The Macroeconomic Impact of Coal-Fired Power Plants

edited by

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The economic analysis in this study is based on certain conditions that include fuel prices for power generation and capital costs of power stations. Some country data are not consistent across their sources. For instance, the forecast gross domestic products (GDPs) of India and Indonesia were derived from the study of the Economic Research Institute for ASEAN and East Asia (ERIA), while the forecast GDP for South Africa was derived from the study of the Institute of Economic Energy, Japan (IEEJ). Therefore, the results of this study, as calculated, should be dealt with carefully; if more comprehensive and detailed data become available, further investigation is recommended to enhance their credibility. The results are not meant to pre-empt international discussions for making rules.

Preface

The demand for electricity is steadily rising in East Asia Summit (EAS) member countries, and a continued trend is anticipated. The necessity for low-cost electricity is growing and affects people's lives and the power industry's competitiveness. Based on these, coal-fired power plants (CPPs) seem to increasingly play an important role in supplying electricity to the EAS region in the future.

On the other hand, the power generation of CPPs, compared to other types, is known as the worst in gas emission. Member countries of the Organisation for Economic Co-operation and Development (OECD) argue that multilateral development banks (MDBs) and export credit agencies (ECAs) should limit financial support for CPPs.

As both are equally important, we need to find ways to balance these two considerations. This study aims to quantify a macroeconomic impact of CPPs in selected countries to improve understanding of the necessity of CPPs, and to provide ideas to balance different requirements by employing high-efficiency power generation technology.

We hope that outcomes from this study will serve as reference for policymakers in EAS countries and contribute to the improvement of energy security in the region as a whole.

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List of Abbreviations

ASEAN	Association of Southeast Asian Nations
BAU	business as usual
CCS	carbon capture and sequestration 3-2
CO_2	carbon dioxide
CPP	coal-fired power plant
EAS	East Asia Summit
ECAs	export credit agencies
EIA	Energy Information Administration
ERIA	Economic Research Institute for ASEAN and East Asia
GDP	gross domestic product
GW	gigawatt
HHV	high heat value
IEA	International Energy Agency
IEEJ	The Institute of Energy Economics, Japan
IGCC	integrated coal gasification combined cycle
IGFC	integrated coal gasification fuel cell combined cycle
LCOE	levelised cost of electricity
LHV	low heat value
MDB	multilateral development bank
MW	megawatt
O&M	operation and maintenance
OECD/NEA	Organisation for Economic Co-operation and Development–Nuclear Energy Agency
SC	super critical
SOFC	solid oxide fuel cell
TWh	terawatt-hour
UK	United Kingdom
US	United States
USC	ultra supercritical

CHAPTER 1

Financial Aid for Coal-fired Power Plants

In this chapter, we establish the present status of coal-fired power plants (CPPs) in ASEAN countries and India, and study cases of support by public financial institutions for construction of CPPs.

1.1. Importance of Coal-fired Power Generation

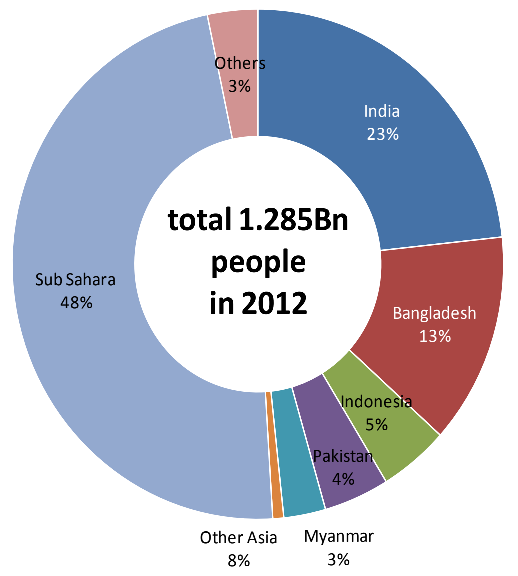
A. Importance of Coal in Economic Development

Improving access to electricity, supplying low-cost electricity, and lowering pollution are the important issues facing the electric power sector in the developing countries.

As many as 1.285 billion people in the world have had no access to electricity as of 2012[1] and supplying them with electric power remains a serious challenge (Figure 1.1). The global demand for electric power is expected to reach 40,104 TWh in 2040, approximately 1.8 times higher than in 2012. This issue is particularly serious among the developing countries in Asia where the average income and purchasing levels are low, and where there is a demand for supply of electric power at the lowest price possible. This demand is a significant issue that concerns industrial competitiveness, as well as the concomitant air and water pollution and climate change problems it poses to human beings. Under these circumstances, electric power supply with low environmental load becomes more necessary.

[1] International Energy Agency, *World Energy Outlook 2014*.

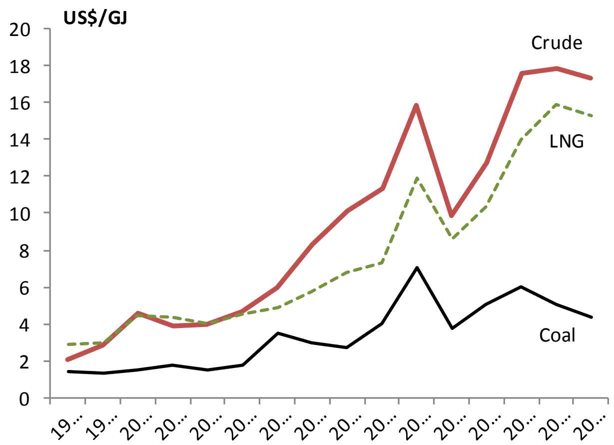
Figure 1.1: Populations Without Access to Electricity



Source: International Energy Agency, *World Energy Outlook 2014.*

There is, therefore, a demand to develop on a large scale low-cost and clean power source in developing countries. One answer is high-efficiency coal-fired power generation, considered superior to other power generation methods in terms of economic efficiency. Coal exists abundantly as fuel, but its high environmental load strips itself of merits although this can be offset by high-efficiency power generation technology.

Figure 1.2: Fossil Fuel Price



Crude oil: OECD cif. LNG: Japan cif. Coal: Asian market price
Cif = cost, insurance and freight, GJ = gigajoule, LNG = liquefied natural gas.
Source: BP, *Statistical Review of World Energy,* June 2014.

B. Current Use of Coal in Power Generation

Coal-fired power generation has been increasing in several developing countries such as India, Indonesia, and South Africa, where it provides stable supply of electric power.

If we take a look at the power-generation technology utilised for coal-fired power generation, we find an overwhelming ratio of subcritical pressure-power generation, followed by supercritical pressure-power generation at 10–25 percent. On the other hand, ultra supercritical pressure-power generation, the technology with the highest efficiency currently available, is not being utilised in any country. This indicates that power-generation efficiency still has room for improvement. To lower its environmental load, it is necessary to combust coal as efficiently as possible, but the methods used by developing countries leave a lot to be desired.

Figure 1.3: Power Generation Mix

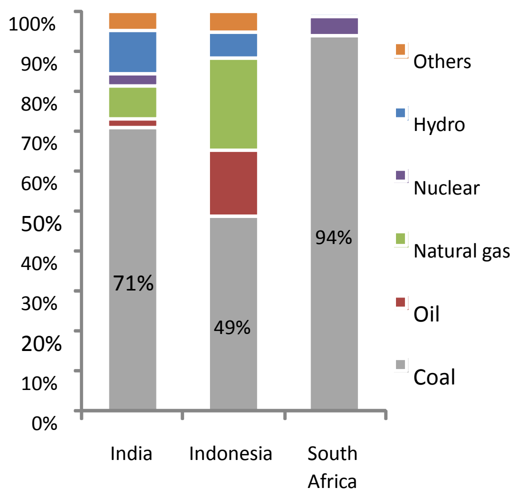
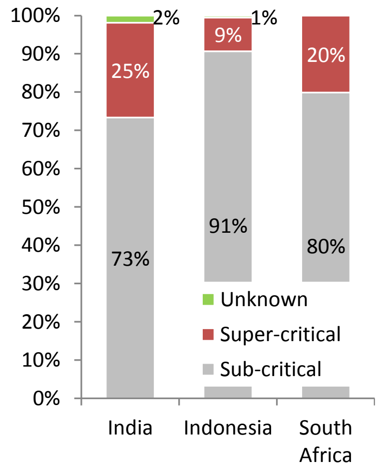


Figure 1.4: Share of Technology in Coal-fired Power Plants



kWh base, 2012 existing + under construction

CPP = coal-fired power plant, kWh = kilowatt-hour.

Source: (Fig 1-3) International Energy Agency, *Energy Balance 2014*;

(Fig 1-4:) Platts, 'UDI World Electric Power Plants Database September 2012'.

1.2. Overview of Coal-fired Power Plants in Study Target Countries

This section provides overviews of the circumstances of coal-fired power generation in the ASEAN countries and India. We chose the CPPs from the Platts 'UDI World Electric Power Plants Database June 2014' and used these as database after excluding private power-generation plants. Included in this database are the CPPs in Cambodia, India, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Viet Nam.

A. Coal-fired Power-generating Capacity by Operational Status

Table 1.1 shows the coal-fired power-generating capacity by operational status based on the database. The total power-generating capacity is 751 GW. India accounts for 76 percent of the total at 567 GW, followed by Viet Nam at 63 GW (eight percent), and Indonesia at 62 GW (eight percent). The power plants in the planning stage account for 51 percent of the total at 387 GW, followed by those in operation at 194 GW (26 percent), and those under construction at 114 GW (15 percent).

The database covers 762 power plants and 2,232 power-generation units.

Table 1.1. Capacity of Coal-fired Power Plants, by Operational Status

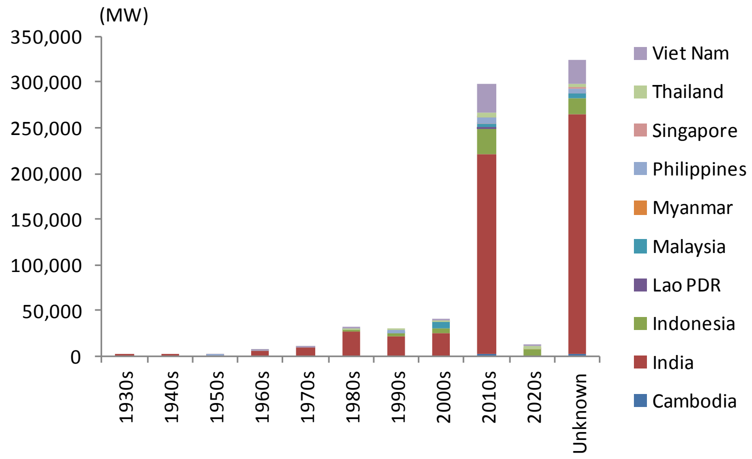
Unit: MW

Country	Operational Status										Total
	OPR	CON	PLN	DEL	CAN	DEF	DAC	STN	RET	UNK	
Cambodia	130	405	3,570		350						4,455
India	147,713	90,192	290,803	6,872	9,080	17,830	600	50	3,922	59	567,120
Indonesia	21,652	4,624	34,153	670	930	270					62,299
Lao PDR		1,878									1,878
Malaysia	7,929	2,080	4,800		1,300	1,400					17,509
Myanmar	128		1,480	12							1,620
Philippines	5,498	1,597	6,936		587	1,250			10		15,878
Singapore	102	60				1,200					1,362
Thailand	5,265		5,740		4,550				285		15,840
Viet Nam	5,860	13,313	39,027	30		4,520			195		62,945
Total	194,277	114,149	386,509	7,584	16,797	26,470	600	50	4,411	59	750,905

Note: CAN = Cancelled, CON = Under construction, DAC = Deactivated/mothballed, DEF = Deferred without construction start, DEL = Delayed after construction start, MW = megawatt, OPR = In commercial operation, PLN = Planned and still in design, RET = Retired, STN = Shutdown or standby, UNK = Unknown operational status (typically assigned to old plants).
Source: Platts, September 2012.

Figure 1.5 shows the coal-fired power-generating capacities of the ASEAN countries and India, in increments of 10 years. The figures for 2010s include the power plants in operation, under construction, and in the planning stage. Many power plants with unknown start period of operation are in the planning stage and their start year is not mentioned in the database.

Figure 1.5: Capacity of Coal-fired Power Plants, by Age



MW = megawatt.
Source: Platts, September 2012.

B. Supplier Countries of Major Power-generation Facilities

We now look at the countries which supply major power-generation facilities such as boilers, turbines, and generators. The names of the manufacturers in the database were used to determine the supplier countries, whereas the places of origin were used in the case of multinational corporations. In cases of joint ventures between a particular country and an overseas manufacturer, the country of the manufacturer providing technology was regarded as the supplier country.

It is necessary to understand that a country supplying facilities is not always a facility-exporting country or a funding country.

a. Boilers

Table 1.2 shows the power-generating capacity of boilers from countries with known suppliers. In the database, the total coal-fired power generating capacity of the study target countries is 751 GW, but the power-generating capacity of boilers from known supplier countries is 365 GW. The difference (386 GW) stems from the fact that supplier countries of these boilers are unknown and that many of the power plants are in the planning stage.

In the case of India, domestic manufacturers supply 45 percent of boilers. In all the target countries of the study, Chinese manufacturers supply 31 percent of the total number of boilers, followed by Japanese manufacturers at eight percent, and Korean manufacturers at five percent. The rest are domestically manufactured boilers.

Table 1.2: Countries Supplying Boilers to ASEAN Countries and India

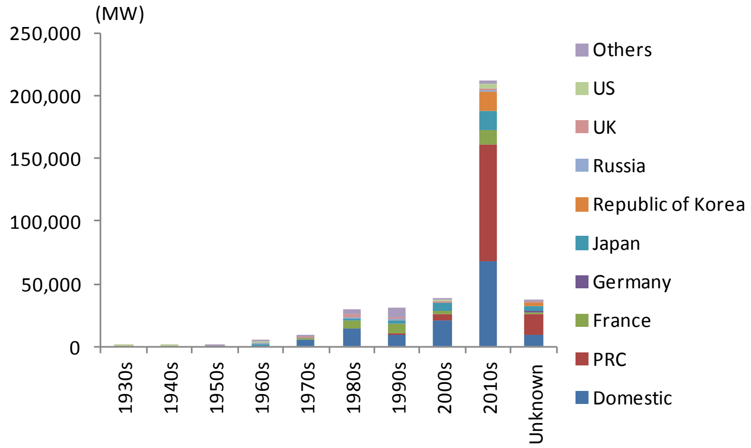
Unit: MW

Country	Domestic	China	France	Germany	Japan	Korea	Russia	UK	US	Others	Total
Cambodia		120								10	130
India	128,728	83,733	26,133	743	16,167	13,900	6,148	5,438	2,526	5,036	288,550
Indonesia	78	12,085	660		2,409	700			1,320	7,170	24,422
Lao PDR		1,878									1,878
Malaysia		480	4,180		7,349						12,009
Myanmar		132									132
Philippines		1,470	1,344		2,512	206			1,344	2,197	9,073
Singapore					102						102
Thailand		540			1,434	700			731	2,685	6,090
Viet Nam		13,313	100			2,400	1,002	1,840	3,480		22,135
Total	128,806	113,751	32,417	743	29,973	17,906	7,150	7,278	9,401	17,098	364,521

MW = megawatt, PRC = People's Republic of China, UK = United Kingdom, US = United States.
Source: Platts, September 2012.

Figure 1.6 shows the supplier countries of boilers from the 1930s to the present. The supply volume from Chinese manufacturers has been increasing in the 2010s. Many power plants with unknown operation start periods are in the planning stage and their operation start periods are not mentioned in the database.

Figure 1.6: Countries Supplying Boilers, by Age



MW = megawatt, PRC = People's Republic of China, UK = United Kingdom, US = United States.
Source: Platts, September 2012.

b. Turbines

Table 1.3 shows the power-generating capacity of turbines supplied by countries with known suppliers. In the database, the total coal-fired power-generating capacity of the target countries of the study is 751 GW, but the power-generating capacity of turbines from known supplier countries is 367 GW. The difference (384 GW) stems from the fact that the other supplier countries are unknown and that many power plants are in the planning stage.

In the case of India, domestic manufacturers supply 44 percent of turbines. In all the target countries, Chinese manufacturers supply 31 percent of the total number of turbines, followed by Japanese manufacturers at 15 percent, and French manufacturers at four percent. The rest are domestically manufactured turbines.

Table 1.3: Countries Supplying Turbines to the ASEAN Countries and India

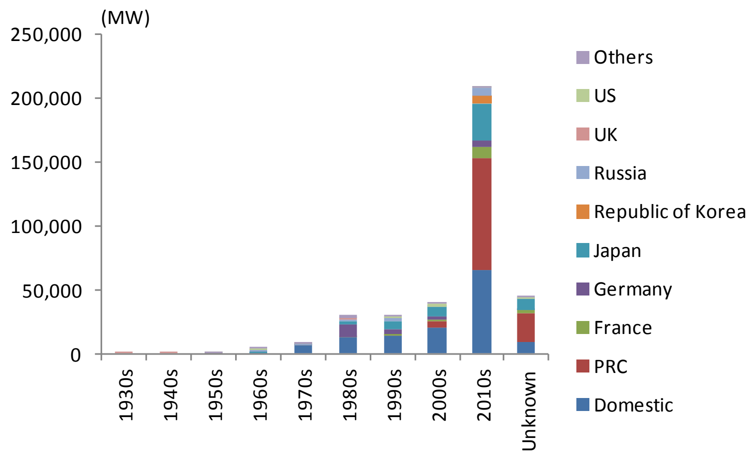
Unit: MW

Country	Domestic	PRC	France	Germany	Japan	Korea	Russia	UK	US	Others	Total
Cambodia		525			10						535
India	127,427	87,645	8,840	17,620	28,076	1,370	9,676	2,715	3,517	5,031	291,917
Indonesia		12,666	504	1,360	8,085	700			1,340		24,655
Lao PDR		1,878									1,878
Malaysia		480	4,180		6,349				1,000		12,009
Myanmar		132									132
Philippines		1,200	1,999		3,912	206			902	655	8,874
Singapore					102						102
Thailand		540	300	127	5,234	700			304	285	7,490
Viet Nam		10,223			4,360	3,480	1,002		600	8	19,673
Total	127,427	115,289	15,823	19,107	56,128	6,456	10,678	2,715	7,663	5,979	367,264

MW = megawatt, PRC = People's Republic of China, UK = United Kingdom, US = United States.
Source: Platts, September 2012.

Figure 1.7 shows the power generated by turbines from supplier countries over the years. The supply volume of Chinese manufacturers has been increasing in the 2010s. Many power plants with unknown start period of operation are in the planning stage and their start year of operation is not mentioned in the database.

Figure 1.7: Capacity of Turbines from Supplier Countries over the Years (Country Total)



MW = megawatt, PRC = People's Republic of China, UK = United Kingdom, US = United States.
Source: Platts, September 2012.

c. Generators

Table 1.4 shows the power-generating capacity of generators from known supplier countries. In the database, the total coal-fired power-generating capacity of the target countries of the study is 751 GW, but the power-generating capacity of generators from known supplier countries is 366 GW. The difference (385 GW) stems from the fact that the rest of supplier countries are unknown and that many power plants are in the planning stage.

In the case of India, domestic manufacturers supply 47 percent of generators. In all the target countries, Chinese manufacturers supply 31 percent of the total power capacity, followed by Japanese manufacturers at 15 percent, and French manufacturers at four percent. The rest is from domestically manufactured generators

Table 1.4: Countries Supplying Generators to ASEAN Countries and India

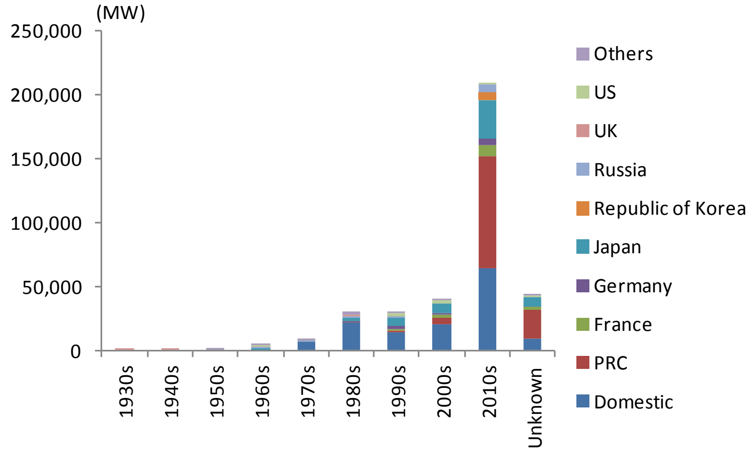
Unit: MW

Country	Domestic	China	France	Germany	Japan	Korea	Russia	UK	US	Others	Total
Cambodia		120								10	130
India	128,728	83,733	26,133	743	16,167	13,900	6,148	5,438	2,526	5,036	288,550
Indonesia	78	12,085	660		2,409	700			1,320	7,170	24,422
Lao PDR		1,878									1,878
Malaysia		480	4,180		7,349						12,009
Myanmar		132									132
Philippines		1,470	1,344		2,512	206			1,344	2,197	9,073
Singapore					102						102
Thailand		540			1,434	700			731	2,685	6,090
Viet Nam		13,313	100			2,400	1,002	1,840	3,480		22,135
Total	128,806	113,751	32,417	743	29,973	17,906	7,150	7,278	9,401	17,098	364,521

MW = megawatt, UK = United Kingdom, US = United States.
Source: Platts, September 2012.

Figure 1.8 shows the power capacity of generators from supplier countries over the years. The supply volume of Chinese manufacturers has been increasing quickly. Many power plants with unknown start period of operation are in the planning stage and, thus, their start years are not mentioned in the database.

Figure 1.8: Capacity of Generators from Supplier Countries over the Years (Country Total)



MW = megawatt, PRC = People's Republic of China, UK = United Kingdom, US = United States.
Source: Platts, September 2012.

1.3. Support to Coal-fired Power Generation by Public Financial Institutions

This section summarises the study results on the financial support by public financial institutions for construction of CPPs and others in the target countries. The study was done through the project databases or press releases of public financial institutions. It does not cover all CPPs.

The amount of support funds is not included because the study focuses mainly on examining the power-generating capacity of the CPPs supported by public financial institution and also because the years of support and currency used differ, the scopes of supported projects differ from one public financial institution to another, and the forms of financing differ from one project to another.

A. Examined Public Financial Institutions

Table 1.5 lists the examined public financial institutions and the dates of availability of information about them. The information on the financial support of the World Bank Group and the Asian Development Bank (ADB) for the construction of CPPs in the target countries of the study was extracted from the project database. The information on financial support by the other public financial institutions for the construction of CPPs in the target countries of the study were collected from mid-August to the end of September 2014 from press releases at their websites. Updated information after October 2014 is not included.

Since the purpose of the study is to examine the coal-fired power-generating capacity of the power plants financially supported by public financial institutions, information from specified CPPs was collected. The types of target financial support were project finance, export finance, and loan guarantee. Once confirmed, any case of financial support by public financial institutions was examined regardless of the amount. Financial support for private power generation was excluded from the study.

As shown in Table 1.5, information is available from the World Bank Group and ADB. For the other public financial institutions, however, old information is not always available. In the case of Chinese public financial institutions, specific financial support information has not been published.

It is necessary to note that this study does not cover all financial support.

Table 1.5: List of Examined Public Financial Institutions

Public Financial Institution	Country	Available Information
Asian Development Bank (ADB)	Multilateral	All
European Investment Bank (EIB)	Multilateral	1980-
European Bank for Reconstruction and Development (EBRD)	Multilateral	1991-
World Bank Group (IBRD/IDA/IFC/MIGA)	Multilateral	All
Export Development Canada (EDC)	Canada	2011-
Bank of China	China	NA
China Development Bank	China	NA
China Exim Bank	China	NA
Sinosure	China	NA
Compagnie Francaise d'Assurance pour le Commerce Exterieur (COFACE)	France	2011-
Deutsche Investitions- und Entwicklungsgesellschaft (DEG)	Germany	2009-
Euler Hermes	Germany	2010-
Kreditanstalt für Wiederaufbau (KfW)	Germany	2007-
Servizi Assicurativi del Commercio Estero (SACE)	Italy	2006-
Japan Bank for International Cooperation (JBIC)	Japan	FY2004-
Nippon Export and Investment Insurance (NEXI)	Japan	1998-
Export-Import Bank of Korea (Kexim)	Korea	1995-
Korea Export Insurance Corporation (KEIC)	Korea	NA
Netherlands Development Finance Company (FMO)	Netherlands	2008-
Garanti-instituttet for eksportkreditt (GIEK)	Norway	2010-
CESCE	Spain	2009-
Geschäftsstelle für die Exportrisikogarantie (ERG)	Switzerland	2010-
Commonwealth Development Corporation (CDC)	United Kingdom	2005-
Export Credits Guarantee Department (ECGD)	United Kingdom	2010-
Overseas Private Investment Corporation (OPIC)	United States	2009-
US Export-Import Bank	United States	1996-

Note: The World Bank Group consists of the International Bank for Reconstruction and Development, the International Development Association, the International Finance Corporation, and the Multilateral Investment Guarantee Agency.

B. Financially Supported Coal-fired Power-generating Capacity

Cases of financial support by public financial institutions for coal-fired power generation were confirmed in India, Indonesia, Philippines, and Viet Nam. Table 1.6 shows the coal-fired power-generating capacity by operational status for which financial support was confirmed, and a ratio of financially supported power-generating capacity to total power-generating capacity. The ratio is calculated by dividing the ‘financially supported power-generating capacity in the total power-generating capacity’ by the ‘total power-generating capacity.’

The coal-fired power-generating capacity supported by public financial institutions totalled 56,859 MW in the target countries, or 7.6 percent of the total power-generating capacity. Since the database includes closed power plants and cancelled construction of power plants, the total power-generating capacity of 750,905 MW is considered a maximum denominator value for calculating financial support ratio. Also, since the financially supported coal-fired power-generating capacity of 56,859 MW does not cover all cases, it is considered a minimum numerator value for calculating a ratio. Accordingly, though the 7.6 percent ratio of the supported power-generating capacity to the total power-generating capacity is considered a minimum value, it is actually assumed to be higher than this.

Of the countries receiving support, the scale of power-generating capacity is overwhelmingly higher in India. In terms of the ratio to the total power-generating capacity, however, Indonesia and the Philippines have a higher financial support reception rate.

The number of power plants confirmed to be financially supported was 45 whereas that of power-generation units was 130.

Table 1.6: CPP Capacity Financially Supported by Public Financial Institutions

Unit: MW

Country	Coal-fired power plant generation capacity with financial aid											Total	Share
	Operational Status										Sub-Total		
	OPR	CON	PLN	DEL	CAN	DEF	DAC	STN	RET	UNK			
Cambodia												4,455	
India	24,140	7,300		2,400					507		34,347	567,120	6.1%
Indonesia	11,220										11,220	62,299	18.0%
Lao PDR												1,878	
Malaysia												17,509	
Myanmar												1,620	
Philippines	2,738										2,738	15,878	17.2%
Singapore												1,362	
Thailand	1,434										1,434	15,840	9.1%
Viet Nam	1,200	5,920									7,120	62,945	11.3%
Total	40,732	13,220		2,400					507		56,859	750,905	7.6%

Note: CAN = Cancelled, CON = Under construction, DAC = Deactivated/mothballed, DEF = Deferred without construction start, DEL = Delayed after construction start, MW = megawatt, OPR = In commercial operation, PLN = Planned and still in design, RET = Retired, STN = Shutdown or standby, UNK = Unknown operational status (typically assigned to old plants).
Source: Platts, September 2012.

Constructing a CPP requires a huge amount of money and the initial investment increases for technology with higher power-generation efficiency. For this reason, construction of CPPs in developing countries may be financed by multilateral development banks (MDBs) and economic credit agencies (ECAs). In financing coal-fired power generation, MDBs and ECAs of advanced countries have set strict criteria for improving power-generation efficiency and reducing environmental load, a measure taken to strike a balance of stability, economic efficiency, and environmental friendliness in an electric power source.

Table 1.7 shows the financially supported coal-fired power generating capacity by confirmed public financial institutions. Looking at MDBs, the coal-fired power-generating capacity where the World Bank Group is involved was a total of 22,277 MW (ADB/IFC/Kexim joint financing included), while that of the CPPs was 12,479MW (same as above).

Table 1.7: CPP Capacity Financially Supported by Public Financial Institutions (Total of Study Target Countries)

Institution	MW
IBRD/IDA	16,807
IFC	1,320
ADB	4,534
ADB/IFC/Kexim	4,150
ADB/Kexim	3,060
ADB/JBIC	735
JBIC	5,350
JBIC/NEXI	12,892
JBIC/NEXI/Kexim	700
JBIC/NEXI/US ExIm/OPIC	1,340
Kexim	1,240
US ExIm	4,731
Total	56,859

Note: ADB = Asian Development Bank, IBRD = International Bank for Reconstruction and Development, IDA = International Development Association, IFC = International Finance Corporation, JBIC = Japan Bank for International Cooperation, Kexim = Export–Import Bank of Korea, MW = megawatt, NEXI = Nippon Export and Investment Insurance, OPIC = Overseas Private Investment Corporation, US Eximbank = Export-Import Bank of the United States.
Sources: Websites of institutions.

1.4. Conclusion

Based on the above summary, the following can be pointed out regarding financing by public financial institutions of coal-fired power generation in the ASEAN countries and India.

- Except from those of the World Bank Group and ADB, the availability of financing information before the 1990s was extremely limited.
- In the database, India's coal-fired power-generating capacity is considerably higher than tha of ASEAN member countries.
- Share of Chinese manufacturers' supply has been increasing with the upsurge of coal-fired power-generating capacity from the 2010s, including the CPPs under construction and in the planning stage.
- Comprehensive financing, which does not identify a power plant, was also confirmed. In such a case, it is tough to identify the target power plant for financing.

In this study, the coal-fired power-generating capacity supported by public financial institutions was confirmed to be 7.6 percent of the total power-generating capacity of the target countries under study. Given the limitations of this study, however, the numerical values obtained through this study do not seem to have fully reflected the reality: the ratio of coal-fired power-generating capacity funded by public financial institutions is estimated to be higher.

CHAPTER 2
Comparison of Technologies

2-1. Higher Efficiency of Coal-fired Power Plants

Coal-fired power generation is achieved by coal combustion through a boiler, heating high-pressure water in a heat-transfer pipe by high-temperature combustion gas to produce steam that runs a turbine. The principle of thermodynamics states that power-generation efficiency becomes higher as steam temperature and steam pressure increase. How high-temperature, high-pressure steam is utilised to generate power is key to higher power-generation efficiency. Once it boils, water changes into steam. As pressure gets higher, the boiling point also increases. Once pressure reaches a critical point (374ºC, 22.1 MPa), water is turned into a supercritical fluid without boiling. A power-generation system utilising a boiling phenomenon at a temperature lower than the critical point is called a subcritical pressure unit, and another utilising the conditions exceeding the critical point is called a supercritical (SC) pressure unit; the latter system ensures higher efficiency. A system which further increases the steam temperature and pressure to over 600ºC is called an ultra supercritical (USC) pressure unit; it currently realises the highest power-generation efficiency in power generation by pulverised coal firing. Realising this USC pressure power-generation plant requires steel pipes for boilers to resist inner steam oxidation and outer high-temperature corrosion, in addition to having high-temperature strength. Nippon Steel & Sumitomo Metal has developed the 'new 18 percent chromium contained steel' and 'new 25 percent chromium contained steel' considered as having the world's highest strength and available as the world's first steel pipes for boilers, thus greatly contributing to realisation of the USC pressure power-generation plant. These steel pipes have now become the global standard and account for 80 percent of global market share. To further enhance the thermal efficiency of coal-fired power generation, the development of advanced USC technology is being promoted with the end view of its practical use around 2020.

Targeting higher efficiency, the development of integrated coal gasification combined cycle (IGCC) is being promoted. This cycle converts coal at a gasification furnace into synthetic gas consisting of carbon monoxide (CO) and hydrogen (H_2). The gas is combusted as a fuel for a gas turbine which generates power and, at the same time, discharges high-temperature exhaust gas to a heat-recovery steam generator to produce steam so as to generate power through a steam turbine as well. As a double power-generation system combining gas and steam turbines, IGCC can realise power-generation efficiency that is more than five percent higher than conventional coal-fired power generation. IGCC has been commercially operated in Europe and the United States (US); its commercial operation started in Japan in 2013. IGCC mainly features availability of low-grade coal with a low ash-melting point (brown coal), which is not easily available for conventional pulverised coal-fired power generation. Global reserves of brown coal are huge and its price is lower than bituminous coal. If IGCC spreads accordingly, the cost of coal-fired power generation is expected to be reduced.

IGCC is designed to gasify coal and generate power by utilising gas and steam turbines. Under study is the integrated coal gasification fuel cell combined cycle (IGFC) which, with the addition of fuel cell to the cycle, creates triple cycle power generation. Its power-generation efficiency is 55 percent (sending end

[2], HHV[3]), and, thus far, more than 15 percent higher in efficiency than coal-fired power generation. The fuel cell is key to this system and utilisation of solid oxide fuel cell (SOFC) is assumed. Small SOFCs have been commercialised for household use, but large SOFCs with high power generation for industrial use have yet to be put into practical use. The realisation of this system will lead to super-high-efficiency coal-fired power generation capable of greatly reducing greenhouse gas.

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[2] Refers to output at the power plant outlet. Because part of the generated electric power (sending end: gross) is used for running various internal facilities of the power plant, output at the power plant outlet (sending end: net) is slightly reduced.

[3] HHV = High heat value. Also called gross calorific value, its value is higher than the low heat value (LHV) or net calorific value by contained latent heat (heat of condensation) of steam. For this reason, power-generation efficiency by HHV standards is lower than that by LHV standards.

Figure 2.1: IGCC System Configuration

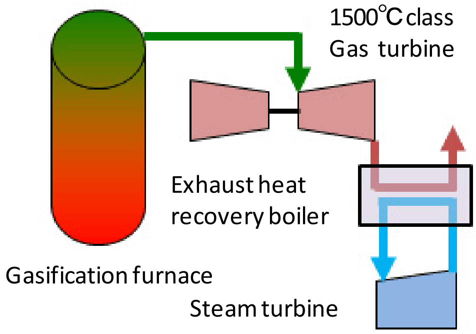
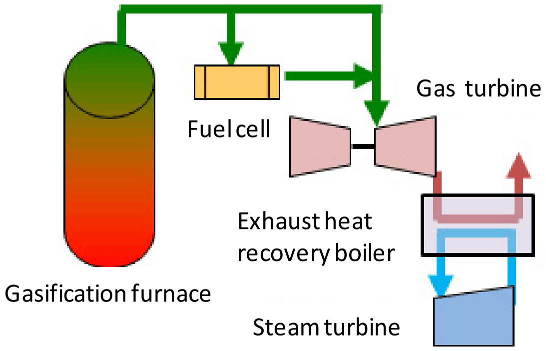
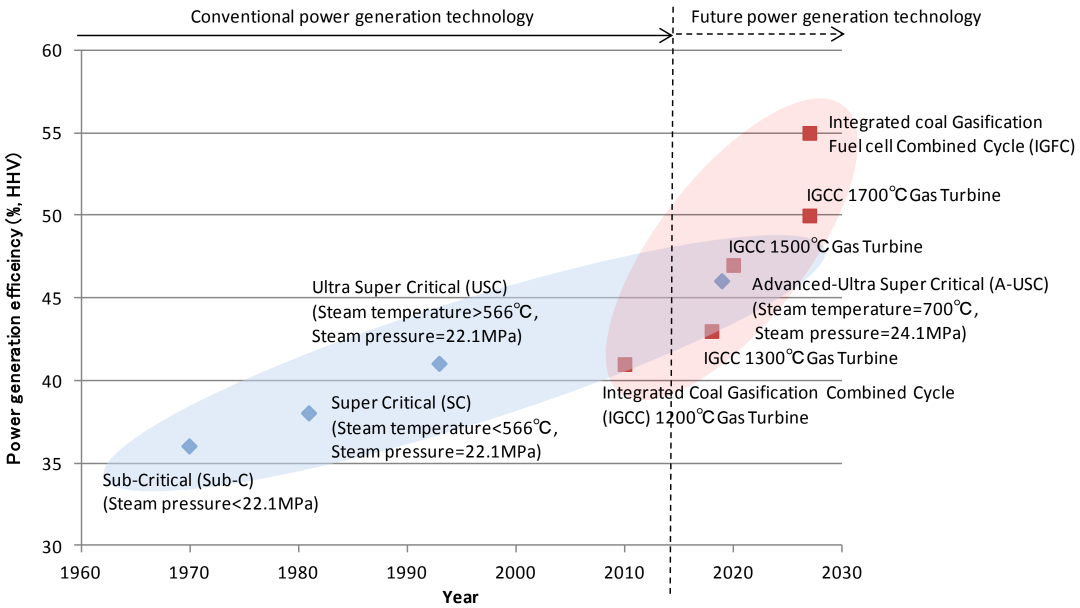


Figure 2.2: IGFC System Configuration



IGCC = integrated coal gasification combined cycle, IGFC = integrated coal gasification fuel cell combined cycle.
Source: Japan Coal Energy Center.

Figure 2.3: History of Efficiency Improvements in Coal-fired Power Plants



CPP = coal-fired power plant, HHV = high heat value.
Source: Ministry of Economy, Trade and Industry, Agency for Natural Resources and Energy, 13th Fundamental Issues Committee Materials.

2-2. Thermal Efficiency of Coal-fired Power Plants

Table 2.1 shows examples of the thermal efficiency of CPPs currently operating in the world. The highest power-generation efficiency is 45 percent to 46 percent (generating end LHV). Bituminous coal and brown coal are used, but the plants using bituminous coal tend to have higher power-generation efficiency by several points.

Table 2.1: Thermal Efficiency of Up-to-Date Coal-fired Power Plants (Global)

Area	Country	Technology	Coal type	Generation capacity（MW）	Gross thermal efficiency (% LHV)
North America	Mexico	Sub Critical (Sub-C)	Bituminous	1312	40
	USA	Sub Critical (Sub-C)	Bituminous	600	39
	USA (EPRI)	Super critical (SC)	Bituminous	750	41
Europe	Belgium	Super critical (SC)	Bituminous	750	45
		Super critical (SC)	Bituminous	1100	45
	Czechoslovakia	Sub Critical (Sub-C)	Lignite	600	43
		Sub Critical (Sub-C)	Lignite	300	42
	Germany	Super critical (SC)	Bituminous	800	46
		Super critical (SC)	Lignite	1050	45
	Netherlands	Ultra Super critical (USC)	Bituminous	780	46
	Slovakia	Super critical (SC)	Lignite	300	40
	Euroelectric	Super critical (SC)	Bituminous	760	45
		Super critical (SC)	Lignite	760	43
Asia pacific OECD	Australia	Super critical (SC)	Bituminous	690	39
		Super critical (SC)	Bituminous	698	41
		Ultra Super critical (USC)	Bituminous	555	41
		Ultra Super critical (USC)	Bituminous	561	43
		Super critical (SC)	Lignite	686	31
		Super critical (SC)	Lignite	694	33
		Ultra Super critical (USC)	Lignite	552	33
		Ultra Super critical (USC)	Lignite	558	35
	Japan	Sub Critical (Sub-C)	Bituminous	800	41
		Super critical (SC)	Bituminous	500 class	44.5
		Ultra Super critical (USC)	Bituminous	600 class	44
		Ultra Super critical (USC)	Bituminous	700 class	44.5
		Ultra Super critical (USC)	Bituminous	900—1000 class	45
	Republic of Korea	Sub Critical (Sub-C)	Bituminous	767	41
		Sub Critical (Sub-C)	Bituminous	961	42

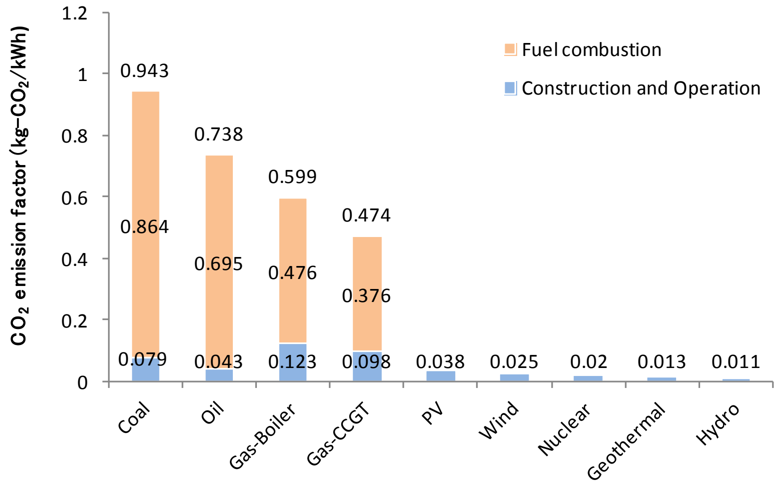
EPRI = Electric Power Research Institute, LHV = low heat value, MW = megawatt, OECD = Organisation for Economic Co-operation and Development, CPP = coal-fired power plant, USA = United States of America.
Sources: International Energy Agency, *Projected Cost of Generating Electricity,* 2010 edition; Ministry of Environment, Government of Japan.

2-3. CO_2 Emissions of Coal-fired Power Plants

Figure 2.4 compares CO_2 emissions, in Japan, of coal-fired power generation with power-generation technologies using petroleum, natural gas, nuclear power, and renewable energy. The life-cycle CO_2-emission factor of CPPs is 0.943kg-CO_2/kWh, the highest among different power-generation systems; it is more than two times higher than natural gas combined cycle power generation. Japanese CPPs have been using subcritical pressure (Sub-C) and supercritical pressure (SC) power-generation systems. With the recent replacement of Japan's CPPs, however, the USC power-generation system has been introduced in many cases, improving the CO_2-emission factor of coal-fired power generation year after year. Compared with petroleum and liquefied natural gas, however,

CO_2 emissions per generated energy are still higher, requiring further improvement of the CO_2-emission factor.

Figure 2.4: Life-cycle CO_2-Emission Factor, by Technology

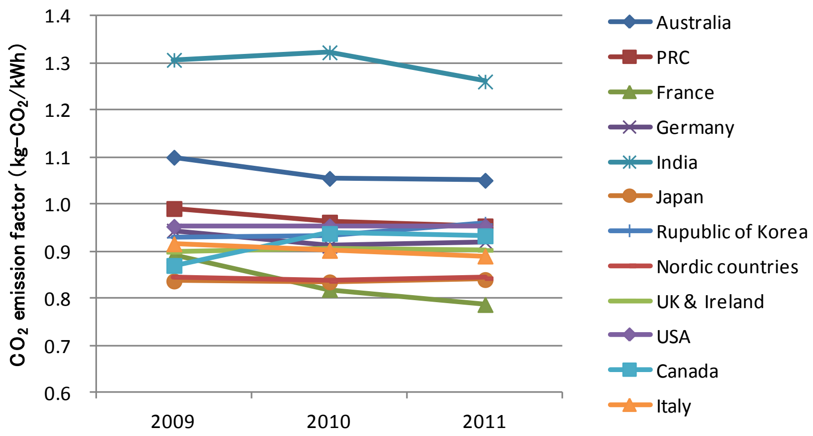


CCGT = combined cycle gas turbine, CO_2 = carbon dioxide, kWh = kilowatt-hour, PV = photovoltaics.
Source: Central Research Institute of Electric Power Industry, *Evaluation of Life-cycle CO_2 Emissions by Power Source,* 2010.

Figure 2.5 compares CO_2 emissions by coal-fired power generation in different countries. The CO_2 emission factors of CPPs differ greatly from one country to another, with India having the highest at 1.3kg-CO_2/kWh. Many relatively small CPPs operate in India, although their operating rate is low due to coal shortage and other factors. Also, the coal used has high ash content[4] and low design quality. These factors result in lower power-generation efficiency and higher CO_2 emission factor. The CO_2 emission factor in China, another coal-rich country comparable with India, is almost at par with those of the advanced countries. Previously, the CO_2 emission factor in China was as high as that in India. In recent years, the country has actively promoted replacement of its CPPs and introduced up-to-date coal-fired power-generation technology to successfully reduce the CO_2 emission factor. The CO_2 emission factor of CPPs is low in advanced countries, with those in Great Britain and Japan having the lowest.

[4] Because ashes are not combusted, higher ash content hinders combustion and lowers efficiency.

Figure 2.5: CO_2 Emission Factor of Coal-fired Power Plants, by Country



CO_2 = carbon dioxide, CPP = coal-fired power plant, kg = kilogram, kWh = kilowatt-hour, PRC = People's Republic of China, UK = United Kingdom, USA = United States of America.
Source: Ecofys, *International Comparison of Fossil-power Efficiency and CO_2 Intensity*, Update 2014, Table 35.

Table 2.3 shows prediction of CO_2 emission factor of future technologies. This table compares only the CO_2 emission factor associated with coal combustion, not life-cycle CO_2 emission factor. The CO_2 emission factor of the widely used subcritical (Sub-C) pressure-power generation was 0.95 kg-CO_2/kWh, but that of latest USC pressure-power generation has been improved to 0.83 kg-CO_2/kWh. If A-USC pressure-power generation is realised, the CO_2 emission factor is expected to be improved to 0.75 kg-CO_2/kWh. In IGCC, the CO_2 emission factor is expected to be improved to 0.75 kg-CO_2/kWh, equivalent to A-USC pressure-power generation. In IGFC, the CO_2 emission factor is estimated to be further improved to 0.63 kg-CO_2/kWh.

Both A-USC pressure-power generation and IGCC power generation are expected to be put to practical use around 2020, and IGFC around 2025, respectively.

Table 2.2: Prediction of CO_2 Emission Factor of Future Technologies

Technology type	CO_2 emission factor (kg-CO_2/kWh)	Net thermal efficiency （%, HHV）	Status
Sub Critical **(Sub-C)** (Steam pressure<22.1MPa)	0.95	36	Conventional technology
Ultra Super Critical **(USC)** (Steam temperature<566℃ Steam pressure=22.1MPa)	0.83	42	Latest technology
Advanced Ultra Super Critical **(A-USC)** (Steam temperature=700℃, Steam pressure=24.1MPa)	0.75	46	will be commercialized by 2020
Integrated coal Gasification Combined Cycle **(IGCC)**	0.75	46	will be commercialized by 2020
Integrated coal Gasification Fuel cell Combined Cycle **(IGFC)**	0.63	55	will be commercialized by 2025

CO2 = carbon dioxide, kWh = kilowatt-hour.
Sources: Created from Agency of Natural Resources and Energy*, Overview of Electric Power Source and Demand;* New Energy and Industry Technology Development Organization, *Technology Strategy Map 2009*; Report of the cost estimation and review committee.

2-4. Power-generation Cost of Coal-fired Power Plants

Evaluation of power-generation cost varies, depending on how preconditions are set. As a matter of course, power-generation costs differ not only from one country to another, but from one power plant to another even in the same country, if installation conditions are different. This section introduces some examples of typical cost calculations.

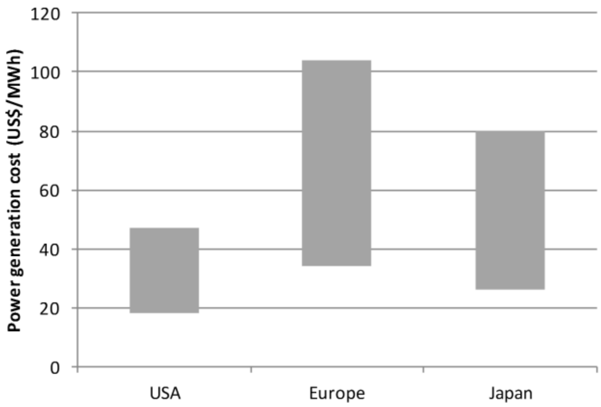
A. International Energy Agency, *World Energy Outlook 2013*

Figure 2.6 shows power-generation cost of existing CPPs according to the *IEA World Energy Outlook 2013.*

Power-generation cost is lowest in North America at approximately US$20–US$40/MWh, and approximately US$30–US$80/MWh in Japan and Europe. Many depreciated CPPs remain in North America as a result of newly constructed power plants being pulled back and/or replaced due to competition with natural-gas-fired power generation (mainly CCGT) in the 1990s, thereby reducing costs in the US. In the wholesale electric-power market in the US, more power plants are capable of gaining higher profits by generating power according to the prices of coal and natural gas; in short, a mechanism that allows high-cost power plants to lose in market competition and low-cost power plants to survive. As an example, when the Henry hub natural-gas price dropped to US$3/MMBtu or even lower due to the shale-gas revolution in North America, natural-gas-fired power generation became less expensive than coal-fired power generation, causing a shift to the former. But after the Henry hub natural-gas price rose to US$4.5–US$5/MMBtu, the competitiveness of CPPs was restored, allowing an increasing number of CPPs to operate again. Thus, the price of the Henry hub natural gas is a factor that decides operation of CPPs in the wholesale electric-power market in the US, and sets the upper limit of power-generation cost.

In Europe, on the other hand, the prices of natural gas and CO_2 emission credit serve as factors to decide operation of CPPs. A shift to CPPs is taking place in Europe due to the high price of natural gas and lagging CO_2 emission credit price. But since natural gas price in Europe is higher than in North America, however, the cost of power generation of CPPs is also relatively high.

Figure 2.6: Comparison of Costs of Coal-fired Power Generation (IEA)

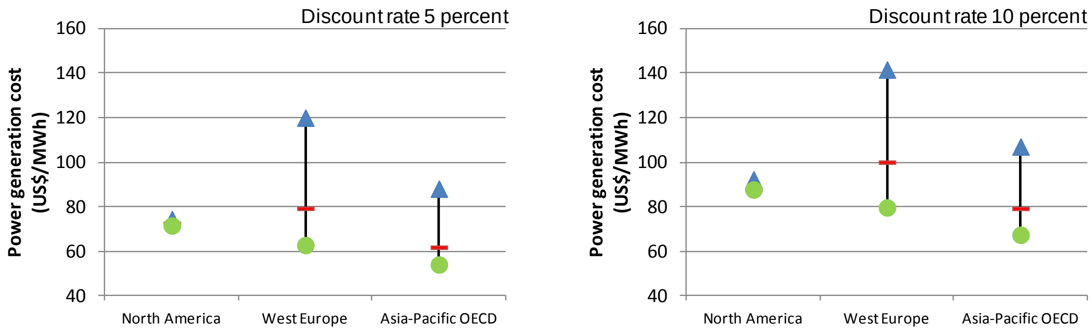


IEA = International Energy Agency, MWh = megawatt-hour, USA = United States of America.
Coal-fired power generation efficiency: 40 percent, Coal price index: US: Central Appalachian coal, Europe: ARA (Amsterdam-Rotterdam-Antwerp) coal, Japan: MCR (McClosky's Coal Report) Japanese market, CO_2 emission right cost included in the European power generation cost.
Source: International Energy Agency, *World Energy Outlook 2013.*

B. Organisation for Economic Co-operation and Development/Nuclear Energy Agency, *Projected Cost of Generating Electricity,* 2010 edition

The levelised cost of electricity or power-generation cost was calculated based on the cost data provided by experts in each country (Figure 2.7). In this calculation, the total life-time cost required for a specific coal-fired power generation project is discounted to the current value and equalised based on annual power generation. Discount rates of five percent and 10 percent are assumed. For a five-percent discount rate, the power generation cost is US$71.5–US$74.4/MWh for North America, US$62.7–US$120.0/MWh for Western Europe, and US$54.0–US$88.1/MWh for Asia and Pacific OECD countries. In case of a 10-percent discount rate, the power generation cost is US$87.7–US$92.3/MWh for North America, US$79.6–US$141.6/MWh for Western Europe, and US$67.3–US$107.0/MWh for Asia and Pacific OECD countries. In this test calculation, the width of power-generation cost is small in the US but large in Western Europe and Asia and Pacific OECD countries. Although this calculation assumes the CO_2 price to be US$30/$CO_2$, the setting of this price decides whether CCS should be introduced and changes the coal-fired power-generation cost. It is a big indefinite factor in calculating the power-generation cost.

Figure 2.7: Comparison of Costs of Coal-fired Power Generation (OECD/NEA)



MWh = megawatt-hour, NEA = Nuclear Energy Agency, OECD = Organisation for Economic Co-operation and Development.
Source: Organisation for Economic Co-operation and Development/Nuclear Energy Agency, *Projected Cost of Generating Electricity,* 2010 edition.

C. World Energy Council, *World Energy Perspective: Cost of Energy Technology*

Table 2.4 shows the World Energy Council's calculation results of levelised cost of electricity, or power-generation cost, of coal-fired power generation. This test calculation assumes a capital-cost discount rate of 10 percent. However, since it is pointed out that investors often ask for a discount rate of 18 percent or more to construct a new power plant, a further increase in the figures could be assumed. The economic efficiency of CPPs in Europe and Australia greatly depends on whether or not a carbon tax is imposed because this test calculation does not include it. For CPPs in PRC, the initial investment cost is as low as US$660,000/MW, or 80 percent of the global average. Even if coal from Australia is used, the power-generation cost would be US$35/MWh, less than half the cost in Europe and the

US.

Table 2.3: Comparison of Coal-fired Power-Generation Costs (WEC)

Area	CAPEX (million US$/MW)	OPEX (US$/MW/year)	Capacity utilization ratio (%)	LCOE (US$/MWh)
PRC	0.66-0.66	32,820-50,000	80	35-39
Australia	2.51-3.70	36,185-60,673	83	93-126
USA	2.94-3.11	29,670-32,820	80-85	77-78
UK	2.27-2.85	30,600-76,500	95-98	119-172

CAPEX = capital expenditure, LCOE = levelised cost of electricity, MW = megawatt, MWh = megawatt-hour, OPEX = operating expense, PRC = People's Republic of China, UK = United Kingdom, USA = United States of America.
Source: World Energy Council, *World Energy Perspective: Cost of Energy Technology,* 2013.

D. Energy Information Administration, *Updated Capital Cost Estimates for Utility Scale Electricity Generating Plants,* April 2013

Table 2.4 shows an analytical example of power-generation cost in the US, according to EIA, and features evaluation of a wide range of power source types. The figures represent only a part of analysis which also covers nuclear power generation, hydroelectric power generation, and different kinds of renewable energy. It also evaluates maintenance costs as well as initial investment. It covers only the US but is useful material for cost comparison amongst power sources.

Table 2.4: Comparison of Costs of Thermal Power Generation (EIA)

	Plant Characteristics		Plant Costs (2012$)		
	Nominal Capacity (MW)	Heat Rate (Btu/kWh)	Overnight Capital Cost ($/kW)	Fixed O&M Cost ($/kW-yr)	Variable O&M Cost ($/MWh)
Coal					
Single Unit Advanced PC	650	8,800	$3,246	$37.80	$4.47
Single Unit Advanced PC with CCS	650	12,000	$5,227	$80.53	$9.51
Single Unit IGCC	600	8,700	$4,400	$62.25	$7.22
Single Unit IGCC with CCS	520	10,700	$6,599	$72.83	$8.45
Natural Gas					
Conventional CC	620	7,050	$917	$13.17	$3.60
Advanced CC	400	6,430	$1,023	$15.37	$3.27
Advanced CC with CCS	340	7,525	$2,095	$31.79	$6.78
Conventional CT	85	10,850	$973	$7.34	$15.45
Advanced CT	210	9,750	$676	$7.04	$10.37

Btu = British thermal unit, CCS = carbon capture and sequestration, CT = combustion turbine, EIA = Energy Information Administration, IGCC = integrated coal gasification combined cycle, kW = kilowatt, MW = megawatt, MWh = megawatt-hour, O&M = operation and maintenance, PC = pulverised combustion.
Source: Energy Information Administration, *Updated Capital Cost Estimates for Utility Scale Electricity Generating Plants,* April 2013.

E. Economic Research Institute for ASEAN and East Asia, *Study on the Strategic Usage of Coal in the EAS Region*

In a 2012 report, the Economic Research Institute for ASEAN and East Asia (ERIA) summarises the efficiency and power-generation cost of coal-fired power generation. The power-generation efficiency, initial investment cost, operating cost, power-generation cost, and CO_2 emissions obtained from actual plant data are described on three coal-fired power-generation systems: subcritical pressure (Sub-C) power generation, supercritical pressure (SC) power generation, and ultra supercritical pressure (USC) power generation.

The figures in Table 2.5 show higher initial investment amount for facilities with higher power-generation efficiency. This is because boiler tubes and other equipment use more expensive special materials capable of withstanding high temperature and high pressure, and more complicated heat-recovery facilities. Coal consumption, however, is lower in case of high-efficiency technology. Thus, if economic efficiency is evaluated over a certain period of a power plant’s operation, the average cost becomes lower for higher-efficiency technology. As a matter of course, higher-efficiency technology emits less CO_2. This is significant as one may be captivated by the low initial investment and thus fail to properly evaluate the true economic efficiency of a power plant over its entire operation period.

Table 2.5: Power-Generation Efficiency and Costs of Different Coal-fired Power Plant Technologies (ERIA)

	Boiler Type		
	Ultra Super Critical (USC)	Super Critical (SC)	Sub-critical (Sub-C)
Thermal Efficiency (%, LHV)	41.5～45.0%	40.1～42.7%	37.4～40.7%
Initial Cost (million US$)	1,298 million US$	991～1,240 million US$	867～991 million US$
Fuel Consumption (ton/year)	2,229,000 tons/year (100%)	2,275,000 tons/year (+2.1%)	2,413,000 tons/year (+8.3%)
CO2 Emission (ton/year)	5,126,000 tons/year (100%)	5,231,000 tons/year (+2.11%)	5,549,000 tons/year (+8.3%)
O&M Cost (million US$/year)	3.42 million US$/year	4.1 million US$/year	5.0 million US$/year
Generation Cost (US$ cent/kWh)	4.03 cent/kWh (100%)	4.19 cent/kWh (+3.9%)	4.44 cent/kWh (+10.2%)
Examples	✓ "Isogo" J-POWER, Japan ✓ "Tachibanawan" J-POWER, Japan ✓ "Nordjylland" Vattenfall, Denmark ✓ "Xinchang" CPI, NSRD and J-Power, China	✓ "Takehara" J-POWER, Japan ✓ "Matsushima" J-POWER, Japan	✓ "Taichung" Taipower, Taiwan ✓ "Thai Binh" EVN, Vietnam

ERIA = Economic Research Institute for ASEAN and East Asia, LHV = lower heat value, CO2 = carbon dioxide, O&M = operation and maintenance, CPI = China Power Investment Corporation, NSRD = Shenzhen Nanshan Power Corporation, EVN = Viet Nam Electricity.

Source: Economic Research Institute for ASEAN and East Asia, *Study on the Strategic Usage of Coal in the EAS Region,* Research Project Report 2012, No. 27.

CHAPTER 3

Prospects of US Finance Regulations for Dissemination of Coal-fired Power Plants

3.1. Overview

The Barack Obama administration, in intensifying its voice on the global warming issue, has positioned the diffusion of clean energy as one of the main pillars of its energy policy.

In January 2010, the US submitted to the United Nations Framework Convention on Climate Change a national-goal plan to reduce greenhouse gas by 17 percent by 2020, with enactment of a relevant domestic law as a provision.

The Climate Action Plan, announced by President Obama in June 2013, emphasises the promotion of spread of renewable energy technology, but also carries a policy that puts the introduction of advanced CCS technology as a precondition for financial support for overseas coal-fired power generation.

In December 2013, the Export-Import Bank of the United States (US Eximbank) introduced major regulations on financing coal-fired power plants (CPPs) and technology export. With that, and taking stock of future consequences of such financing regulations, it is necessary to study and analyse in a multifaceted and comprehensive way the following: 1) environmental regulations on domestic coal-fired power generation, 2) price competitiveness of coal-fired power generation, 3) global framework for climate-change countermeasures, 4) trends of coal-fired power plants and technology export in other countries, and 5) domestic political dynamics.

3.2. Prospects of Financing Coal Projects

A. Export-Import Bank of the United States Regulations

Immediately after the announcement by the Obama administration of the Climate Action Plan in June 2013, the US Eximbank cancelled financing consideration for the Thai

Binh Two Coal-Fired Power Plant in Viet Nam[5]. In the preceding five years until the announcement, the US Eximbank had been financing CPPs in South Africa with US$805 million for a total of 4,000 MW generated power, and India[6] with US$917 million for a total of 4,800 MW generated power.

In December 2013, the US Eximbank announced the Supplemental Guidelines for High-Carbon Projects regulating export of American coal-related facilities. The guidelines call for non-approval of financing for export of facilities related to CPPs unless the prospective recipients are: 1) highest-efficiency CPPs in the poorest countries that have, from an economic viewpoint, no options other than coal-fired power generation, or 2) equipped with the carbon capture and sequestration (CCS) technology[7].

B. Perspectives on the US Limit on Financing Coal Projects Abroad

Such strict regulations by the US Eximbank are a result of campaigns by advocacy groups, including pro-Democrats and environmental non-government organisations, who emphasise the necessity for the US to internationally take active initiatives centred on the climate change issue. Such initiatives, as called for, should not only enhance environmental regulations on domestic coal-fired power generation but limit as well the expansion of overseas coal-fired power generation.

On the other hand, opposing voices (mainly of Democrats from coal-producing states who do not always support the stringent attitude of the Obama administration towards the coal industry, and the majority of Republicans) call for Congress to relax regulations against the coal industry, and ask for a vote with regard to the financing by the US Eximbank of CPPs and technology export. These critics claim that enhancement of global-warming countermeasures will weaken the global competitiveness of the US industry and lose business opportunities under increasing global demand for coal.

The following may offer points to the trend of financing for future US export of coal-fired power generation technology.

[5] Bloomberg *Businessweek*, 18 July 2013.
[6] *The Washington Post*, 27 June 2013.
[7] http://www.whitehouse.gov/the-press-office/2013/06/25/fact-sheet-president-obama-s-climate-action-plan

a. Environmental Regulations on Domestic Coal-fired Power Generation

Since the formation of the Obama administration in 2009, the Environment Protection Agency (EPA) has been enhancing the environmental regulations on thermal power plants in the US.

In December 2011, EPA announced the Mercury and Air Toxic Standard for Power Plants (enforced in April 2012; compliance period until 2015) regulating newly constructed and existing 25-MW or higher thermal power plants (coal-fired and oil-fired), metals such as nickel and chromium, and acid gases such as sulphur dioxide (SO_2) and mono nitrogen oxides (NO_X). It also requires power plants to introduce proven emission-control technology and desulfurisation equipment. A reduction level similar to power plants which have achieved the maximum reduction rate is required for same-scale power plants. It also obligates power plants to install, by 2015 (although up to a two-year extension is allowed), emission-control equipment for hazardous air pollutants.

The EPA regulations are expected to reduce 90 percent of mercury emissions from CPPs, 88 percent of acid-gas emissions, and 41 percent of SO_2 emissions from thermal power plants.

In June 2014, the Clean Power Plan was announced based on Section 111 (d) of the Clean Air Act and intended to reduce CO_2 emissions from power plants (see next section). But with the resistance from the industrial circle concerned about the high costs of replacing or discarding the facilities of existing power plants, and with the Republican party enjoying a majority in both houses of Congress, how stringent the final regulations of the Clean Power Plan would be remains to be seen.

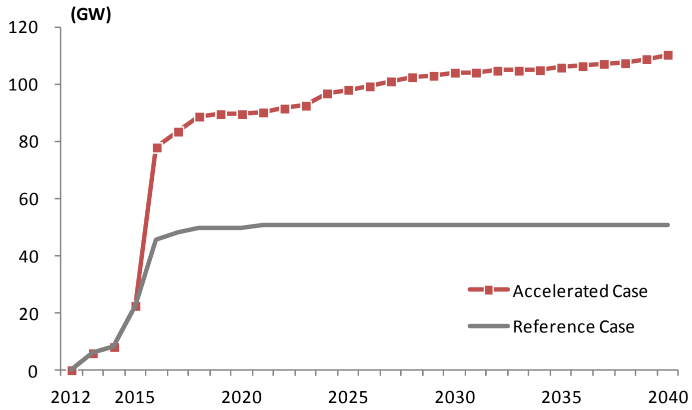
Enhanced US regulations on domestic CPPs will also enhance US incentives to limit the spread of overseas CPPs.

b. Price Competitiveness of Coal-fired Power Generation

One reason more voices are demanding enhanced regulations on CPPs in the US is the lower price of natural gas as a result of the shale gas revolution. With the enhanced price competitiveness of natural-gas-fired with coal-fired power generation and the slowing growth of electric power demand, and enhanced environmental regulations, construction costs of new CPPs and repair costs of the existing ones are rising[8].

According to the *Annual Energy Outlook 2014* published by the Energy Information Administration (EIA), the installed capacity of coal-fired power generation totalling 310 GW (as of 2012) is expected, by 2020, to be reduced by approximately 50 GW in a reference case, and approximately 90 GW in an accelerated case (Figure 3.1).

Figure 3.1: Cumulative Retirement Capacity of Coal-fired Power Plants



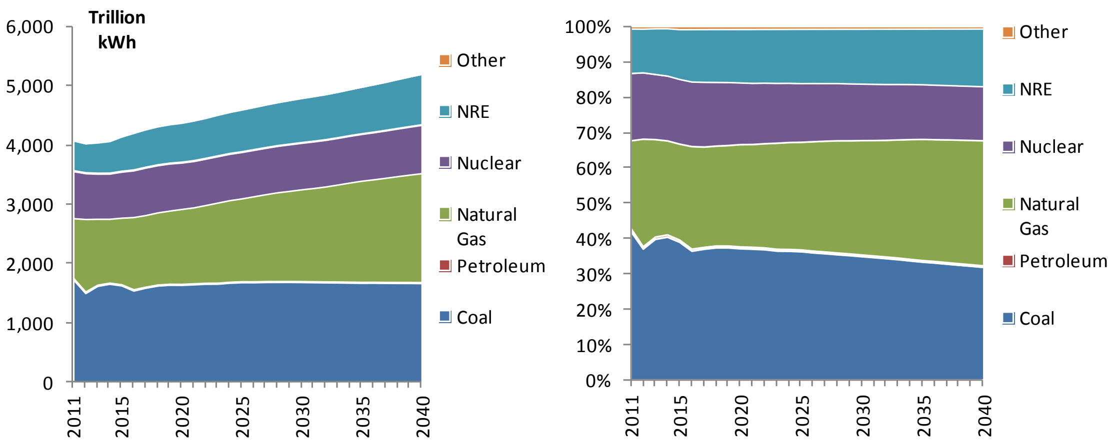
CPP = coal-fired power plant, GW = gigawatt.
Source: Energy Information Administration, *Annual Energy Outlook 2014.*

As of 2013, coal-fired power generation accounted for 40 percent of total power generation in the US.

Coal-fired power generation is estimated to level off at less than 1,700 TWh toward 2040. From 2012 to 2040, gas-fired power generation is expected to increase by 1.5 percent, but coal-fired power generation is expected to increase by only 0.4 percent. On the other hand, even by 2030, the ratio of coal in the power source mix is 35 percent, exceeding natural gas (32 percent). Past the middle of the 2030s, however, the ratios are reversed. By 2040, the ratios of natural gas and coal are expected to be 35 percent and 32 percent, respectively (Figure 3.2).

[8] In March 2014, EIA announced the abolition of a total of 5,360,000 kW-worth of coal-fired power plants after November 2013 as a result of obligation to achieve the MATS standards, slowing electric power demand, and enhanced competitiveness of the natural-gas-fired power plants. It is also expected to abolish additional 60,000,000 kW-worth of coal-fired power plants by 2020. http://www.eia.gov/todayinenergy/detail.cfm?id=15491

Figure 3.2: Electricity Generation, by Fuel (Reference Case)

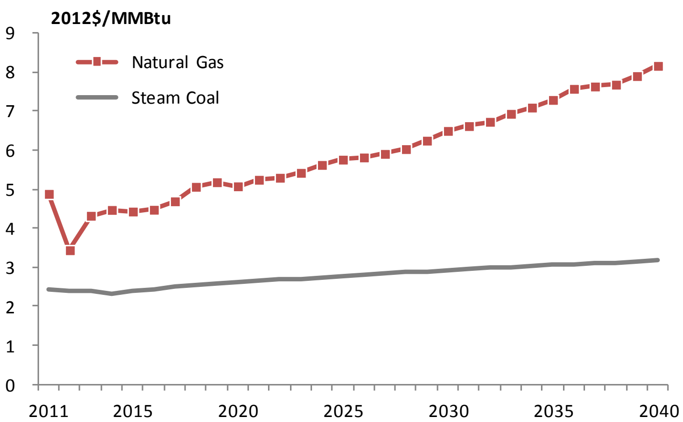


kWh = kilowatt-hour, NRE = new and renewable energy.
Source: Energy Information Administration, *Annual Energy Outlook 2014*.

In the *Annual Energy Outlook 2014* reference case*,* the price of natural gas for power generation in competition with coal is estimated to rise from US$3.44/MBtu in 2012 to US$5.07/MBtu in 2020, and keeping a higher increase rate thereafter (Figure 3.3).

The reference case assumes that increased production of shale gas is realised as expected (i.e. the ratio of shale gas in US natural-gas production would increase from 40 percent in 2012 to 53 percent in 2040). It also takes into account effects on energy price of starting liquefied natural gas export and so forth.

Figure 3.3: Prices of Coal and Natural Gas to Power Sector (Reference Case)



MMBtu = one million British thermal units.
Source: Energy Information Administration, *Annual Energy Outlook 2014.*

Preconditions for this estimation naturally contain uncertainty. For example, increased shale gas production may not be realised at the currently estimated rate due to reasons such as large-scale environmental issues in the future. Also, the price of domestic natural gas may skyrocket due to other reasons. In such a case, coal-fired power generation may not be smoothly phased out in the US due to its higher cost competitiveness. If utilisation of coal-fired power generation cannot be domestically reduced, it will be difficult for it to be financially discontinued internationally.

The price of natural gas will also be affected by fluctuations of the price of crude oil (Table 3.1). In short, if the price of crude oil will rise over a long period, it will also discourage abolition of coal-fired power generation in the US.

Table 3.1: Projected Prices of Crude Oil and Natural Gas

Prices (2012 US$ per unit)

	2012	2020			2030			2040		
		L	R	H	L	R	H	L	R	H
Crude Oil (WTI, barrel)	94.12	66.90	94.57	148.28	69.90	116.99	171.69	72.90	139.46	202.24
Natural Gas (Henry Hub, MBtu)	2.75	4.35	4.38	4.73	5.75	6.03	6.88	7.43	7.65	8.34

L=Low Oil Price; R=Reference; H=High Oil Price

MBtu = million British thermal unit, WTI = West Texas Intermediate; bench mark crude oil in US.
Source: Energy Information Administration, *Annual Energy Outlook 2014.*

c. Global Framework for Climate-Change Countermeasures

By the end of the 21st Conference of the Parties to the United Nations Framework Convention on Climate Change (COP21) in Paris in December 2015, an agreement should have been reached on a legal framework for 2020 or later, in which all countries will participate. An international vote on the reduction obligation of China—the world's largest source of greenhouse gas emissions—will have a great effect on US coal policy. One main reason the US refused to ratify the Kyoto Protocol was China's lack of reduction obligation.

Introspecting on the US refusal to ratify the Kyoto Protocol, the Obama administration has announced a policy to enhance global-warming countermeasures internationally and domestically, while looking forward to taking leadership in the international framework after COP21.

At the US–China summit meeting in November 2014 in Beijing, the US announced its goal of reducing CO_2 emissions by 26–28 percent or less by 2025, whereas China came up with a policy to raise the ratio of non-fossil fuels in the energy mix to around 20 percent, as it expects CO_2 emissions to peak by around 2030. In the international framework for 2020 or later, it is still quite uncertain whether China will accept an internationally binding numerical goal of greenhouse gas emissions. If it refused again to bear an international obligation to achieve the goal, the US would assumedly follow suit.

d. Coal-fired Power Plants and Technology Export Trend in Other Countries

Focusing on Asia, including China and India and the developing countries in other regions, it is virtually unavoidable to see an increase in coal consumption in the predictable future. Under such circumstances, should there be an increase in export of clean coal facilities and technologies from countries outside the US, the latter will very likely cancel or relax the voluntary restraints it set up under the pressure from the domestic industry.

China is America's biggest joint-development partner of clean-coal technology. As described in Chapter 1, however, China is becoming active in exporting CPPs. Already, there are worries about the possibility that exports by American corporations may be disadvantaged by the US Eximbank's control over financing.

e. Domestic Political Dynamics

The Obama administration seems bent on leaving a clean energy policy, including climate-change countermeasures, as its legacy.

With the Republican party enjoying a majority in both houses of Congress and winning gubernatorial election in 24 of 36 states—some of which are leading coal-producing states—it will be more difficult for the Obama administration to obtain congressional support in regulating coal-fired power generation. Already, the Republican party has expressed a strong intention to review environmental regulatory bills promoted by EPA, including the Clean Power Act Plan[9].

9 http://thehill.com/policy/energy-environment/e2-wire/223398-senate-gop-steeling-for-battle-against-the-epa

With two years remaining, the Obama administration is expected to exert efforts to achieve a 'historical result' concerning climate change. Particularly, the US is expected to take the initiative in forming an international framework at COP21. At the same time, a primary election is set to start in January 2016 leading toward the next presidential election in November of the same year. Based on the lessons of the 2014 midterm election and for reasons of sound election strategy, it would not be wise for the Obama administration to excessively stimulate the industrial circle; even the Democrats may not agree should the current administration attempt to enhance the environmental regulations.

3-3. Clean Power Plan

In June 2014, EPA announced the Clean Power Plan to reduce by 30 percent CO_2 emissions from domestic thermal power plants by 2030, with 2005 as reference point.[10]

A. Implementation Plan

The Clean Power Plan provides that EPA shall formulate a CO_2 emission-reduction target value by state and for each state to formulate an implementation plan in response to it and submit it to EPA by June 2016. Should a state require a grace period after submitting the first plan, it has to submit the final version by June 2017 in case of a single-state plan and by June 2018 in case of a multistate plan. After receiving the plan, EPA will announce the result of examination within 12 months.

B. CO_2 Emissions Reduction Goal

The Clean Power Plan targets a 30-percent reduction of CO_2 emissions by 2030 (compared with that of 2005 of 730,000,000 tons).[11] It is the first time for the US to regulate CO_2 emissions from power plants (control of air pollutants such as mercury, SO_2 and NO_x has already been introduced). However, instead of directly controlling emissions of each power plant, CO_2 emissions-reduction target values are set for each state; a two-stage midterm goal (2020–2029) and final goal (2030) are set (Table 3.2).[12]

[10] http://www2.epa.gov/carbon-pollution-standards/clean-power-plan-proposed-rule
[11] As of 2013, CO_2 emissions from American energy sources were 10 percent lower than in 2005. http://www.eia.gov/environment/emissions/carbon/
[12] No target values are set for Vermont and Washington, DC because they have no power plants.

The Clean Power Plan provides up to four building blocks as means to reduce CO_2 emissions; combining those blocks is at the discretion of each state.

Building Block 1:	Higher-efficiency coal-fired power generation (six percent higher thermal efficiency)[13]
Building Block 2:	Higher operating rate of existing natural gas combined cycle (NGCC) (as of 2012, from 44 percent national-average operating rate to 70 percent state-average operating rate)
Building Block 3:	Expanded utilisation of renewable energy and nuclear power (development promotion of renewable energy power sources, operation of existing nuclear power plants, and secure development of nuclear power plants under construction)[14]
Building Block 4:	Improved energy efficiency toward a 1.5 percent annual reduction of power consumption

According to an analysis by the National Economic Research Association Economic Consulting on various effects of the Clean Power Plan, the power loss as a result of abolition of coal-fired power generation capacity between 2014 and 2031 is estimated to be 97 GW in case of combining only building blocks 1 and 2, and 220 GW in case of combining 1 to 4, respectively (Table 3.3).

In October 2014, Ed Whitefield of the energy and commerce committee of the House of Representatives and concurrent chairman of the power subcommittee issued a statement criticising EPA's program as unrealistic, and claiming that if the Clean Power Plan is put into practice, more than 45 GW of coal-fired power generation will be lost, costs of at least more than US$366 billion will be incurred over 15 years, and electric power charge would, on the average, increase from 12 percent to 17 percent across the country.[15]

13 According to EPA's estimation, the cost required to improve thermal efficiency is US$100/kW (2011 price).
14 Including survival of 5.7 GW of nuclear power plants highly likely to be decommissioned.
15 http://energycommerce.house.gov/blog/study-epa%E2%80%99s-power-plan-could-total-least-366-billion

Table 3.2: Target Value for Each State (CO_2 Emission Factor, lb/MWh)

	CO_2 Emissions per Unit (as of 2012)	Provisional Target Rate (2020－2029)	Final Target Rate (2030)	Reduction Rate (2012－2030)
Alabama	1,444	1,147	1,059	27%
Alaska	1,351	1,097	1,003	26%
Arizona	1,453	735	702	52%
Arkansas	1,640	968	910	45%
California	698	556	537	23%
Colorado	1,714	1,159	1,108	35%
Connecticut	765	597	540	29%
Delaware	1,234	913	841	32%
Florida	1,200	794	740	38%
Georgia	1,500	891	834	44%
Hawaii	1,540	1,378	1,306	15%
Idaho	339	244	228	33%
Illinois	1,895	1,366	1,271	33%
Indiana	1,923	1,607	1,531	20%
Iowa	1,552	1,341	1,301	16%
Kansas	1,940	1,578	1,499	23%
Kentucky	2,158	1,844	1,763	18%
Louisiana	1,466	948	883	40%
Maine	437	393	378	14%
Maryland	1,870	1,347	1,187	37%
Massachusetts	925	655	576	38%
Michigan	1,696	1,227	1,161	32%
Minnesota	1,470	911	873	41%
Mississippi	1,130	732	692	39%
Missouri	1,963	1,621	1,544	21%
Montana	2,245	1,882	1,771	21%
Nebraska	2,009	1,596	1,479	26%
Nevada	988	697	647	34%
New Hampshire	905	546	486	46%
New Jersey	932	647	531	43%
New Mexico	1,586	1,107	1,048	34%
New York	983	635	549	44%
North Carolina	1,646	1,077	992	40%
North Dakota	1,994	1,817	1,783	11%
Ohio	1,850	1,452	1,338	28%
Oklahoma	1,397	931	895	36%
Oregon	717	407	372	48%
Pennsylvania	1,540	1,179	1,052	32%
Rhode Island	907	822	782	14%
South Carolina	1,597	840	772	52%
South Dakota	1,135	800	741	35%
Tennesse	1,903	1,254	1,163	39%
Texas	1,298	853	791	39%
Utah	1,813	1,378	1,322	27%
Virginia	1,297	884	810	38%
Washington	763	264	215	72%
West Virginia	2,019	1,748	1,620	20%
Wisconsin	1,827	1,281	1,203	34%
Wyoming	2,115	1,808	1,714	19%

CO_2 = carbon dioxide.
Source: Environment Protection Agency website. https://www.federalregister.gov/articles/2014/06/18/2014-13726/carbon-pollution-emission-guidelines-for-existing-stationary-sources-electric-utility-generating

Table 3.3: Overview of Energy System Impacts of State Compliance Scenarios (Annual Average, 2017–2031)

	Total Coal Retirements through 2031 GW	Coal-Fired Generation TWh	Natural Gas-Fired Generation TWh	Henry Hub Natural Gas Price 2013$/million Btu	Delivered Electricity Price 2013¢/kWh	Electricity Sector CO2 Emissions million metric tons
Baseline	51	1,672	1,212	$5.25	10.8	2,080
State Unconstrained (BB1-4)	97	1,191	1,269	$5.36	12.0	1,624
Change from Baseline	+45	-481	+57	+$0.11	+1.3	-456
% Change from Baseline	+18%	-29%	+5%	+2%	+12%	-22%
State Constrained (BB1-2)	220	492	2,015	$6.78	12.6	1,255
Change from Baseline	+169	-1,180	+802	+$1.53	+1.9	-825
% Change from Baseline	+69%	-71%	+66%	+29%	+17%	-40%

CO_2 = carbon dioxide, BB = building block, Btu = British thermal unit, GW = gigawatt, TWh = terawatt-hour.
Source: National Economic Research Association Economic Consulting, *Potential Energy Impacts of the EPA Proposed Clean Power Plan*.

CHAPTER 4

Macroeconomic Impact of Coal-fired Power Plants

Focusing on India and Indonesia, this chapter quantitatively analyses how the economies of both countries are affected by discontinued financing for coal-fired power generation by multilateral development banks (MDBs) and export credit agencies (ECAs).

4.1. Recent Trends of Financing Policy for CPPs

In June 2013, President Obama announced the Climate Action Plan which, as part of addressing the climate change issue, includes a policy introducing advanced CCS technology as a precondition for financial support for overseas coal-fired power generation.

In response to this, the Export-Import Bank of the United States (US Eximbank) announced in December 2013 major regulations on financing coal-fired power plants (CPPs) and technology export. Thereafter, Denmark, Finland, Iceland, Holland, Norway, Sweden, and Great Britain, among the advanced countries,[16]and the World Bank, European Investment Bank, and European Bank for Reconstruction and Development, among MDBs, one after another announced similar regulations.

In contrast, ADB, ECAs in Japan, and China continue to finance coal-fired power generation.

4.2. Scenario Setting and Methodology

If MDBs and ECAs stop financing the development of coal-fired power generation in developing countries, what influence will be seen? Will it reduce the number of CPPs to be constructed? This study assumes two paths of influence.

The scope of influence of this prediction is up to 2035. For supply–demand prospect, the values in ERIA's *Analysis on Energy Saving Potential in East Asia,* June 2013, were used, unless specified otherwise.

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[16] Ueno et al. (2014), *Quantifying Chinese Public Financing for Foreign Coal Power Plants,* November.

Table 4.1: Description of Scenarios

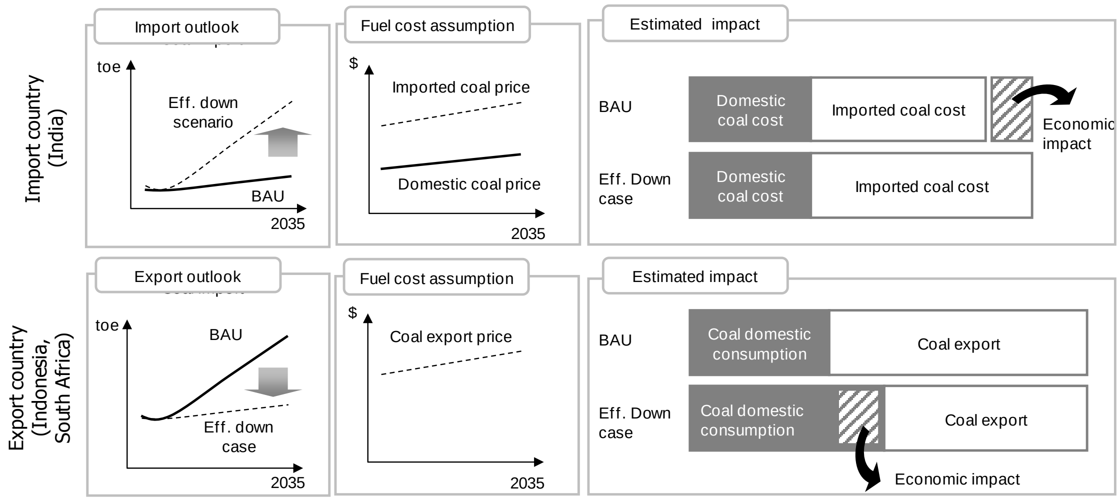
Efficiency Downgrade Scenario	Despite discontinued financing by MDBs and ECAs, construction of coal-fired power plants is continued by using alternative funds. Because no efficiency standards and environmental protection regulations are imposed by MDBs and ECAs, improvement of coal-fired power generation efficiency is delayed.
Gas Conversion Scenario	A project, assuming financing from MDBs and ECAs, is partly deadlocked. Needs for new electric power development are satisfied by a gas-fired power generation project entitled to financing.

A. Efficiency Downgrade Scenario

Coal consumption for power generation becomes higher than in the business-as-usual (BAU) scenario because of reduced power-generation efficiency. If the target of analysis is a net coal-importing country (e.g. India), an increment of coal consumption for power generation directly results in an increase in import volume. Since increased import leads to increased payment, an increment of payment serves as a factor to compound macroeconomic indicators such as gross domestic product (GDP).

If the target of analysis is a coal-exporting country (e.g. Indonesia), an increment of coal consumption for power generation results in a decrease in coal export volume. Since decreased export leads to decreased export income, this decrement badly affects macroeconomic indicators.

Figure 4.1: Path of Influence of the Efficiency Downgrade Scenario



BAU = business as usual, Eff. = Efficiency.
Source: Authors.

Based on objective foundation, it is difficult to quantitatively indicate the influence of discontinued financing by MDBs and ECAs on lower coal-fired power-generation efficiency. There is not enough information to measure the degree of financing by MDBs and ECAs, as described in Chapter 1. For this reason, this study observes the width of influence by assuming a five-percent across-the-board drop based on future expectation of average power-generation efficiency in the target countries.

Table 4.2: Assumption of Average Efficiency of Coal-fired Power Plants

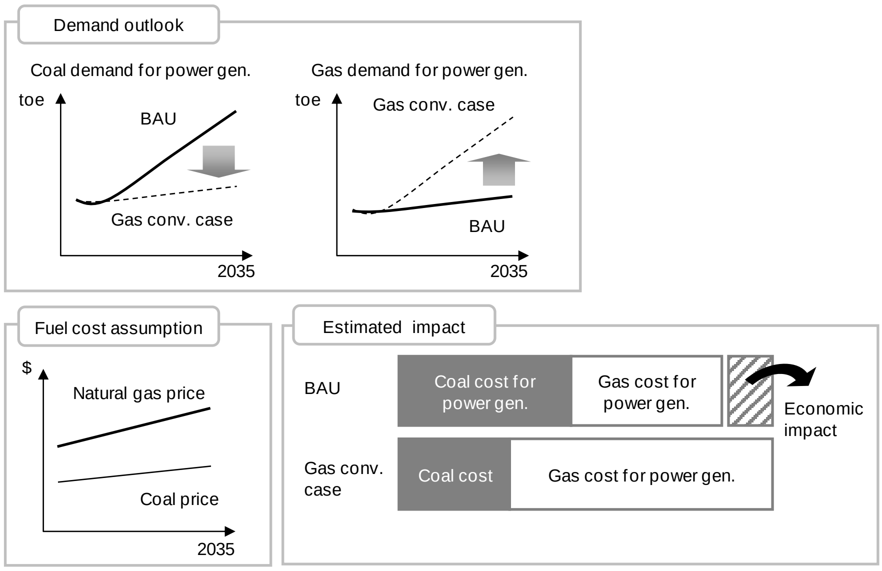
Average efficiency in:	India	Indonesia
BAU scenario	37.6% *	38.7% **
Efficiency down scenario	32.6% (BAU -5%)	33.7% (BAU -5%)

BAU = business as usual, CPP = coal-fired power plant.
* Economic Research Institute for ASEAN and East Asia, *Analysis on Energy Saving Potential in East Asia,* June 2013, BAU scenario.
** Institute of Economic Energy, Japan, *Asia/World Energy Outlook 2013,* Reference scenario.
Source: Authors.

B. Gas-conversion Scenario

Coal consumption becomes lower than in the BAU scenario by a conversion of construction plan from coal-fired to gas-fired power generation, and natural-gas consumption increases to the contrary. A shift to gas-fired power generation means higher fuel cost because natural gas is more expensive than coal. It was assumed that target country would make up for an increment of natural gas demand by import. Increased consumption of natural gas results in higher import of natural gas, creating bad effects on the macro economy.

Figure 4.2: Path of Influence of the Gas Conversion Scenario



BAU = business as usual, conv. = conversion, gen = generation.
Source: Authors.

Based on objective foundation, it is difficult to quantitatively indicate how a shift from coal-fired to gas-fired power generation is affected by discontinued financing from MDBs and ECAs. The degree of financing by MDBs and ECAs, as described in Chapter 1, cannot be measured as there is not enough information. For this reason, this study observes the width of influence by assuming that 15 percent and 30 percent will be converted into gas-fired power generation across the board according to the future prospect of generated energy by coal-fired power generation in the target countries.

Table 4.3: Assumption of Fuel Share in Power Generation

		India	Indonesia
BAU scenario	Coal	67.7% *	42.0% *
	Gas	15.3% *	28.4% *
15%	Coal	-10.1%	-6.3%
Gas conversion		(-15% of 67.7%)	(-15% of 42.0%)
scenario	Gas	+10.1%	+6.3%
30%	Coal	-20.3%	-12.6%
Gas conversion		(-30% of 67.7%)	(-30% of 42.0%)
scenario	Gas	+20.3%	+12.6%

BAU = business as usual.
*ERIA, *Analysis on Energy Saving Potential in East Asia,* June 2013, BAU scenario.
Source: Authors.

C. Combined Scenario

As described, efficiency downgrade and gas conversion scenarios are assumed here. Are these contradictory events occurring independent of each other? Is the occurrence probability of each scenario much the same?

First, regarding the contradictoriness of the scenarios, these events occur at the same time and not independently of each other. Effects of discontinued financing differ depending on the target project. Accordingly, it is only natural to presume that reactions also differ, i.e. one project decides to employ low-efficiency but also inexpensive power-generation technology as an alternative and another decides a shift to gas-fired power generation. A combination of the two scenarios is likely to occur in reality.

Next, for occurrence probability, the efficiency downgrade scenario has higher probability because it conforms to the behavioural principle of profit-seeking corporations, whereas a shift to gas-fired power generation, which compounds economic efficiency, runs counter to that. Of course, economic efficiency is not the only element in deciding investment. For instance, a changing financing environment for coal-fired power generation and expected future enhancement of environmental regulations are risk factors in a coal-fired power plant construction project. If these are considered big risks, a shift to gas-fired power generation can be an appropriate option.

Based on these considerations, this study analyses the following three cases.

Table 4.4: Case Setting

	Eff. downgrade	Gas conversion
Efficiency downgrade case	-5% than BAU	-
Combination scenario 1	-5% than BAU	15% of CPPs will be converted
Combination scenario 2	-5% than BAU	30% of CPPs will be converted

BAU = business as usual, CPP = coal-fired power plant, Eff. = Efficiency.
Source: Authors.

D. Assumption of Fuel Costs

In the analysis, the change of coal or natural gas export/import volume brought about by each scenario is converted into monetary value which requires an assumption of fuel prices.

The domestic fuel prices in the target country were first calculated based on statistical data published by a typical electric company, etc. in the relevant country, and with the assumption that those prices would not change in the future.

Next, the international prices related to export/import used the 2035 nominal prices in the *IEA World Energy Outlook 2013*.

Table 4.5: Assumption of Fuel Costs for Power Generation

		India	Indonesia
Coal price	domestic	n.a.	$80/tonne *
	import	$110/tonne **	n.a.
	export	n.a.	$110/tonne **
Gas price	domestic	n.a.	$14.9/MMBtu **
	import	$14.9/MMBtu **	n.a.

MMBtu = million British thermal units, n.a. = not applicable.
* MEMR, *Handbook of Energy & Economic Statistics of Indonesia.*
** International Energy Agency, *World Energy Outlook 2013,* New Policy Scenario.
Source: Authors.

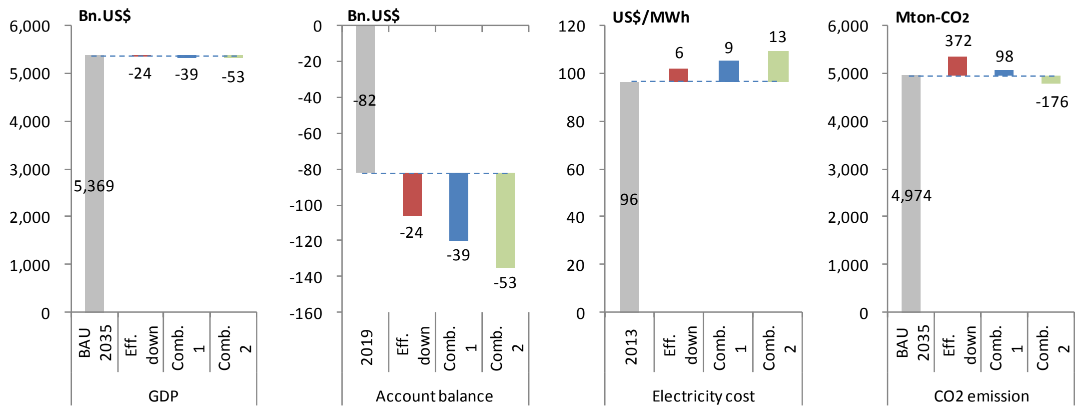
4.3. Calculation Results

A. India

The calculation result indicates that the Indian macroeconomy is influenced by delayed efficiency improvement of coal-fired power generation and a shift to gas-fired power generation. The degree of influence increases in the order of efficiency downgrade, combination 1, and combination 2, corresponding to approximately 1 percent increase of GDP (2035), 28 percent increase of current account balance (2019), and 13 percent increase of electricity charge at maximum.

On the other hand, CO_2 emissions are reduced more as shift volume to gas-fired power generation becomes larger. In the case of combination 2, CO_2 emissions are expected to be four percent lower than in the case of BAU. However, in the case of combination 1, for instance, CO_2 emissions become higher than in the case of BAU because increased CO_2 emissions due to lower efficiency cannot be offset by a reduction effect brought about by a shift to gas-fired power generation.

Figure 4.3: Calculated Result (India)



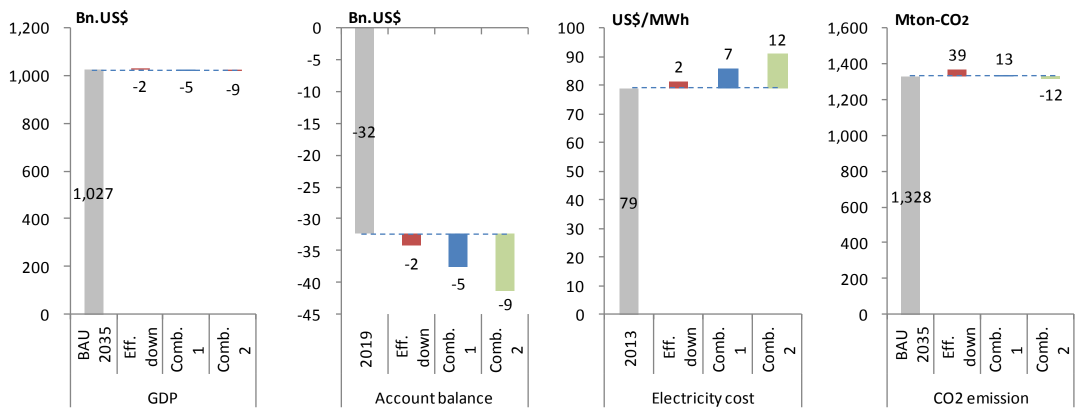
BAU = business as usual, Bn = billion, CO_2 = carbon dioxide, Comb. = Combination, Eff. = Efficiency, GDP = gross domestic product, Mton = megaton, MWh = megawatt-hour.
Electricity price in 2013: Simple average of sector-wise tariff effective during FY2013.
Sources: Economic Research Institute for ASEAN and East Asia, *Analysis on Energy Saving Potential in East Asia,* June 2013, BAU scenario; International Monetary Fund, *World Economic Outlook April 2014*; CEA.

B. Indonesia

The calculation result indicates that the Indonesian macroeconomy is influenced by delayed efficiency improvement of coal-fired power generation and a shift to gas-fired power generation. The degree of influence increases in the order of efficiency downgrade, combination 1, and combination 2, corresponding to 0.9 percent increase of GDP (2035), 28 percent increase of current account balance (2019), and 16 percent increase of electric charge (2013) at maximum.

On the other hand, CO_2 emissions are reduced more as shift volume to gas-fired power generation becomes larger. In the case of combination 2, CO_2 emissions are expected to be one percent lower than in the case of BAU. However, in the case of combination 1, for instance, CO_2 emissions become higher than in the case of BAU because increased CO_2 emissions due to lower efficiency cannot be offset by a reduction effect brought about by a shift to gas-fired power generation.

Figure 4.4: Calculated Result (Indonesia)



BAU = business as usual, Bn. = billion, CO_2 = carbon dioxide, Comb. = Combination, Eff. = Efficiency, GDP = gross domestic product, Mton = megaton, MWh = megawatt-hour.
Electricity price in 2013: Simple average of sector-wise tariff effective during FY2013.
Sources: Economic Research Institute for ASEAN and East Asia, *Analysis on Energy Saving Potential in East Asia,* June 2013, BAU scenario; International Monetary Fund, *World Economic Outlook,* April 2014; PLN.

4.4. Conclusion

Discontinuation of financing for coal-fired power generation by MDBs or ECAs may influence electric power development in the developing countries. The most likely scenario is that although use of alternative funds will continue to help construction of CPPs, improvement of coal-fired power generation efficiency will be delayed by the abolition of efficiency standards and environmental protection regulations imposed by MDBs and ECAs. It is also predicted that projects to develop new CPPs will be partly deadlocked based on the premise of financing by MDBs and ECAs, and electric power development needs will be provided by gas-fired power generation.

This study chose India and Indonesia, which greatly depend on coal for power generation, and analysed the influence of potential scenarios on their macroeconomies. As a result, it was found that these scenarios were likely to have negative effects. In a scenario where improvement of coal-fired power generation efficiency is delayed, the country's GDP, current account balance, and electric charge are adversely influenced by increased coal import volume and decreased coal export volume. In case a shift to gas-fired power generation advances, those factors are adversely influenced through an increased natural gas import volume. A shift to gas-fired power generation contributes to reduced CO_2 emissions, but cannot offset increased CO_2 emissions due to concurrent delayed improvement of coal-fired power generation efficiency, possibly allowing higher emissions than in a BAU scenario.

CHAPTER 5

Impact on Coal-producing Countries

This chapter analyses how coal-exporting countries are influenced when multilateral development banks (MDBs) and export credit agencies (ECAs) discontinue financing coal-fired power generation.

5.1. Scenario Setting and Methodology

A. Paths of Influence and Case Setting

What influences result when MDBs and ECAs discontinue financing the development of coal-fired power generation in developing countries?

When assuming efficiency downgrade and gas conversion scenarios in Chapter 4, the current account balance of the coal-exporting country is adversely influenced by the latter scenario. If a coal-fired power generation project is replaced by a gas-fired one, future demand for coal in that country will decrease. Import volume drops in a country where coal supply depends on import, resulting in decreased coal export volume in a coal-exporting country.

In contrast, lower coal-fired power generation efficiency increases demand for coal. Accordingly, contrary to the above, a coal-importing country increases import volume and a coal-exporting country increases export volume. In short, lower coal-fired power generation efficiency for a coal-exporting country is effective in offsetting decreased coal export volume brought about by the gas conversion scenario.

Table 5.1: Case Setting

	Efficiency Downgrade	Gas Conversion
Efficiency downgrade case	-5% than BAU	-
Combination scenario 1	-5% than BAU	15% of CPPs will be converted
Combination scenario 2	-5% than BAU	30% of CPPs will be converted

BAU = business as usual, CPP = coal-fired power plant.
Source: Authors.

B. Subject Countries

Of the two countries evaluated in Chapter 4, Indonesia has an abundant volume of domestic coal resources and exports coal. Thus, the influence of discontinued financing by MDBs and ECAs is seen taking place only in India as a change of coal import volume. This chapter analyses how the coal-producing countries are influenced by the change of coal import volume in India.

According to a study report by the Ministry of Economy, Trade and Industry,[17] steam coal for power generation will be exported to India by Australia, Indonesia, Mozambique, South Africa, the US, and other countries in 2040. Accordingly, these countries are candidates for analysis. If India cuts down on import of steam coal, it is only natural that the countries with higher coal export to India will be influenced more. The same report says Australia, Indonesia, and South Africa—three major coal-producing countries—are expected to maintain high coal export volume to India up to 2040. With a balance considered between coal resources possessed and future domestic demand, these three seem to remain as major export countries even in 2035. This chapter targets these three countries for analysis.

In case India actually cuts down its coal import volume, the reduction would differ from one supplier country to another. The following is assumed to simplify this study:

[17] Ministry of Economy, Trade and Industry (2013), *Study on Coal Supply-Demand Trend in Asia Pacific and Atlantic*, March.

・ Coal import volume balance by India’s supplier country in 2035 is identical with that in 2040 in the study report by the Ministry of Economy, Trade and Industry (Table 3.2).

・ Variation of India’s coal import volume is proportionally divided among the top three supplier countries according to their import volume ratios in 2035.

Table 5.2: Outlook of Thermal Coal Export and Import in 2040

		to											
		North America	Latin America	OECD Europe	Africa	Middle East	non-OECD Europe	Japan	China	India	South Korea Chinese Taipei	Other Asia	total
from	USA	4.8	9.9	20.0				0.6	5.3	2.8			43.4
	Canada			2.5				2.1	0.3		1.4		6.3
	Colombia	5.2	58.1	29.3	5.0			0.6	1.5		1.0		100.8
	Russia			52.0		10.8	8.8	12.5	22.2		17.7		123.9
	South Africa			10.0	12.2	15.7		0.6	13.0	**44.3**	7.0	5.2	108.0
	Mozambique				0.1	1.7				9.0			10.8
	China							2.8			5.7		8.5
	Indonesia			5.0		5.0		25.0	83.2	**98.4**	58.3	90.3	365.2
	Australia		40.0			13.0		59.5	51.0	**196.1**	59.6	150.0	569.2
	Other Asia						0.8	0.9	32.5	3.3	1.4		38.9
	Others			19.0			22.2			1.0			42.2
	total	10.1	108.0	137.8	17.3	46.2	31.8	104.6	209.0	354.9	152.1	245.5	1,417.3

OECD = Organisation for Economic Co-operation and Development.
Source: Ministry of Economy, Trade and Industry, *Study on Coal Supply–Demand Trend in Asia-Pacific and Atlantic,* March 2013.

C. Assumption of Fuel Cost

This analysis converts the change of coal export volume into monetary value, with assumption of fuel prices as requirement.

The estimated price in 2035 in the *IEA World Energy Outlook 2013* was used as the coal export price.

Table 5.3: Assumption of Fuel Cost for Power Generation

	Australia	Indonesia	South Africa
Coal price export	$110/tonne*		

* IEA, *World Energy Outlook 2013,* New Policy Scenario.
Source: Authors.

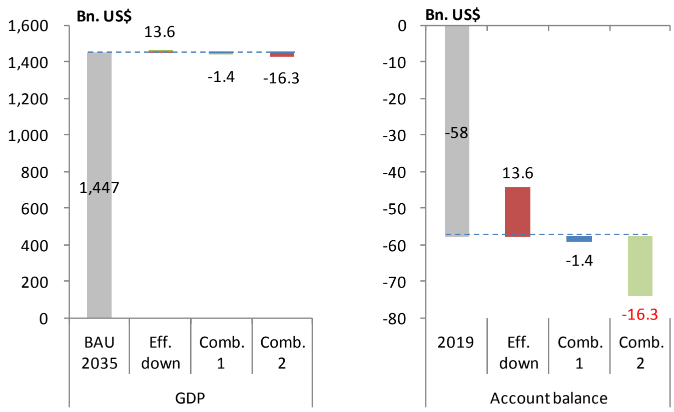
5.2. Calculation Results

A. Australia

The calculation result indicates that delayed improvement of coal-fired power generation efficiency and a shift to gas-fired power generation have both good and bad effects on the Australian macroeconomy. The degrees of effects differ depending on the case. In the efficiency downgrade scenario, an increased coal export volume has positive effects on the Australian economy. Under the calculation conditions, Australia's GDP is boosted by 0.9 percent and its current account balance is improved by 23 percent.

In the combination 1 and combination 2 scenarios, decreased coal export volume by a shift to gas-fired power generation denies an effect of improvement by the efficiency downgrade scenario. Consequently, they lower the GDP by 0.1 percent and 1.1 percent, and the current account balance by 2.4 percent and 28 percent, respectively.

Figure 5.1: Calculated Result (Australia)



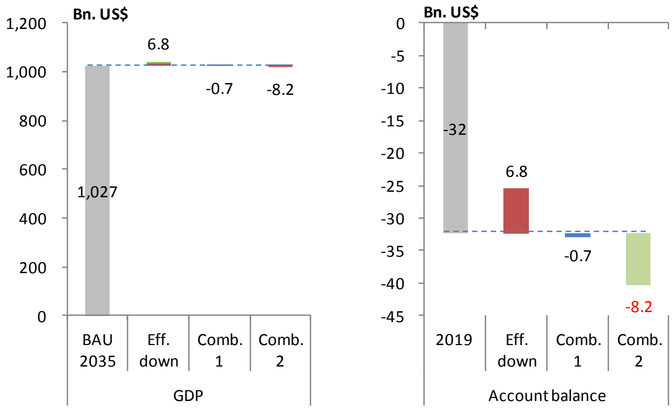
BAU = business as usual, bn = billion, Comb. = Combination, Eff. = Efficiency, GDP = gross domestic product.
Sources: Economic Research Institute for ASEAN and East Asia, *Analysis on Energy Saving Potential in East Asia,* June 2013; BAU scenario: International Monetary Fund, *World Economic Outlook,* April 2014.

B. Indonesia

The calculation result indicates that delayed improvement of coal-fired power generation efficiency and a shift to gas-fired power generation have both good and bad effects on the Indonesian macroeconomy. The degrees of effects differ depending on the case. In the efficiency downgrade scenario, an increased coal export volume has positive effects on the Indonesian economy. Under the calculation conditions, the GDP is boosted by 0.7 percent and the current account balance is improved by 21 percent.

In the combination 1 and combination 2 scenarios, decreased coal export volume by a shift to gas-fired power generation denies an effect of improvement by the efficiency downgrade scenario. Consequently, they lower the GDP by 0.1 percent and 0.8 percent, and the current account balance by 2.1 percent and 25 percent, respectively.

Figure 5.2: Calculated Result (Indonesia)



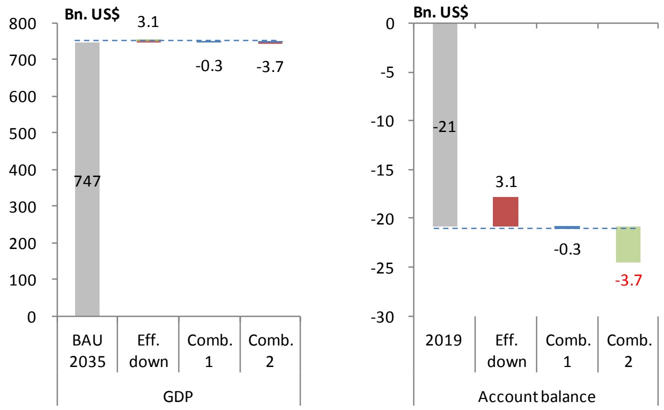
BAU = business as usual, bn = billion, Comb. = Combination, Eff. = Efficiency GDP = gross domestic product.
Sources: Economic Research Institute for ASEAN and East Asia, *Analysis on Energy Saving Potential in East Asia,* June 2013; BAU scenario: International Monetary Fund, *World Economic Outlook*, April 2014.

C. South Africa

The calculation result indicates that delayed improvement of coal-fired power generation efficiency and a shift to gas-fired power generation have both good and bad effects on the South African macroeconomy. The degrees of effects differ depending on the case. In the efficiency downgrade scenario, an increased coal export volume has positive effects on the South African economy. Under the calculation conditions, the GDP is boosted by 0.4 percent and the current account balance is improved by 15 percent.

In the combination 1 and combination 2 scenarios, decreased coal export volume by a shift to gas-fired power generation denies an effect of improvement by the efficiency downgrade scenario. Consequently, they lower the GDP by 0.04 percent and 0.5 percent, and the current account balance by 1.5 percent and 18 percent, respectively.

Figure 5.3: Calculated Result (South Africa)



BAU = business as usual, bn = billion, Comb. = Combination, Eff. = Efficiency, GDP = gross domestic product.
Source: Economic Research Institute for ASEAN and East Asia, *Analysis on Energy Saving Potential in East Asia,* June 2013; BAU scenario: International Monetary Fund, *World Economic Outlook,* April 2014.

5-3. Conclusion

Discontinued financing for coal-fired power generation by MDBs or ECAs may have both good and bad effects on the macroeconomies of the coal-exporting countries. In case discontinued financing delays improvement of power-generation efficiency in coal-importing countries, coal demand, i.e. an increase in coal import, has positive effects on the GDP and the current account balance of coal-exporting countries such as Australia. However, at the same time, it should be noted that this scenario will lead to increase of global air pollution and CO_2 emission.

On the other hand, coal demand is lowered by a shift from coal-fired to gas-fired power generation, seen as simultaneously advancing in the coal-importing countries. Coal import volume may greatly drop depending on a balance between delayed efficiency improvement and a shift to gas-fired power generation. In this case, the GDP and current account balance of the coal-exporting countries are lowered.

A degree of impact depends on amount of coal export to India. As such, Australia would be the most affected country, followed by Indonesia and South Africa. In the case of Australia, impact for current account balance is estimated to range more than +/- 20 percent.

Table 5.4: Consolidated Result of Analysis for Major Coal-exporting Countries

	Impact for	Unit	Benchmark	Scenario		
				Efficiency down	Comb. 1	Comb. 2
Australia	GDP	US$ billion	1,447 [BAU 2035]	+13.6 (+0.9%)	-1.4 (-0.1%)	-16.3 (-1.1%)
	Account balance	US$ billion	-58 [2019]	+13.6 (+23.4%)	-1.4 (-2.4%)	-16.3 (-28.1%)
Indonesia	GDP	US$ billion	1,027 [BAU 2035]	+6.8 (+0.7%)	-0.7 (-0.1%)	-8.2 (-0.8%)
	Account balance	US$ billion	-32 [2019]	+6.8 (+21.3%)	-0.7 (-2.2%)	-8.2 (-25.6%)
South Africa	GDP	US$ billion	747 [BAU 2035]	+3.1 (+0.4%)	-0.3 (-0.0%)	-3.7 (-0.5%)
	Account balance	US$ billion	-21 [2019]	+3.1 (+14.8%)	-0.3 (-1.4%)	-3.7 (-17.6%)

Comb. = Combination, GDP = gross domestic product.
Source: Authors.

CHAPTER 6
Key Findings and Policy Implications

6.1. Key Findings

This study aims to quantitatively grasp and analyse how a macroeconomy is influenced when multilateral development banks (MDBs) and export credit agencies (ECAs) of advanced countries discontinue financing new development of coal-fired power generation.

This report first organised the financing situation for coal-fired power generation (Chapter 1), followed by a comparison of thermal power generation technologies (Chapter 2), and trends of financing for coal-fired power generation in the US (Chapter 3). The report then quantitatively analysed the influence of discontinued financing for coal-fired power generation on the macroeconomies of user countries and coal-importing countries (Chapters 4 and 5).

A. Chapter 1

The existing coal-fired power generation capacity of the study's target ASEAN countries and India totals 751 GW. Of this, only 57 GW capacity has been confirmed to have been financed by public financial institutions in the database used for this study. This accounted for 7.6 percent of total power-generation capacity.

There is a limit to studying the financing information of public financial institutions. For instance, the power plants constructed in the 1970s and 1980s are still running, but the financing situations of such old power plants have not been fully grasped. Many public financial institutions in China have not published their financing information. As a result, the financially supported coal-fired power generation capacity does not cover all events; a ratio of 7.6 percent is estimated to be the minimum. It is safe to presume that more coal-fired power plants (CPPs) are financed in reality.

Table 6.1: Financially Supported CPP Capacity by Public Financial Institutions (Total of Study Target Countries)

Institution	MW
IBRD/IDA	16,807
IFC	1,320
ADB	4,534
ADB/IFC/Kexim	4,150
ADB/Kexim	3,060
ADB/JBIC	735
JBIC	5,350
JBIC/NEXI	12,892
JBIC/NEXI/Kexim	700
JBIC/NEXI/US Eximbank/OPIC	1,340
Kexim	1,240
US Eximbank	4,731
Total	56,859

ADB = Asian Development Bank, CPP = coal-fired power plant, IBRD = International Bank for Reconstruction and Development, IDA = International Development Association, IFC = International Finance Corporation, JBIC = Japan Bank for International Cooperation, Kexim = Export–Import Bank of Korea, MW = megawatt, NEXI = Nippon Export and Investment Insurance, OPIC = Overseas Private Insurance Corporation, US Eximbank = Export-Import Bank of the United States.

Sources: Websites of institutions.

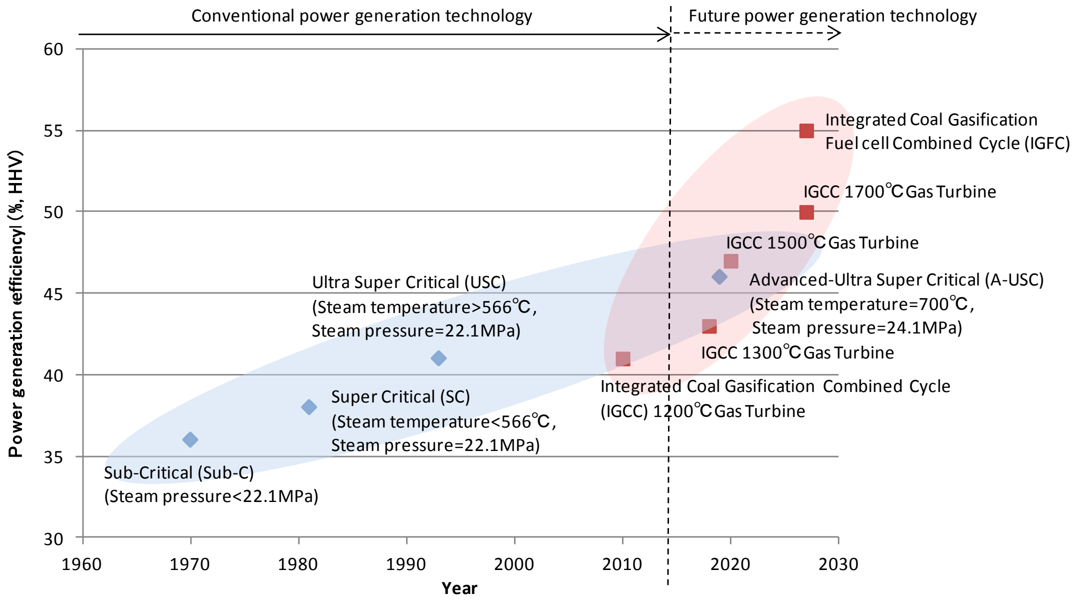
B. Chapter 2

Pulverised-coal-fired power plants have evolved from subcritical pressure (Sub-C) to supercritical pressure (SC) and to ultra supercritical pressure (USC) power plants. All pulverised-coal-fired power plants in advanced countries are supercritical pressure (SC) power plants or above and those to be constructed will be USC pressure power plants. In China, old CPPs have been replaced after 2000 with SC and USC power plants. As a result, the CO_2 emission factor of CPPs in China has been improved to almost the same level as that of the Republic of Korea and Italy.

With higher efficiency as target, advanced USC pressure (advanced-USC) technology is being developed in pulverised-coal-fired power generation. On the other hand, combined cycle power generation with gas turbines or fuel cells (IGCC, IGFC) is being studied, with focus on the advanced countries, so as to greatly improve power-generation efficiency.

Improvement of coal-fired power-generation efficiency not only enhances economic superiority over other power generation systems but controls environmental load, a weakness in coal-fired power generation.

Figure 6.1: History of Efficiency Improvement in CPPs



HHV = higher heat value, MPa = megapascal, CPP = coal-fired power plant.
Source: Ministry of Economy, Trade and Industry, Agency for Natural Resources and Energy, 13th Fundamental Issues Committee Materials.

C. Chapter 3

The Barack Obama administration, in intensifying its voice on the global warming issue, has positioned diffusion of clean energy as one of the main pillars of its energy policy.

In January 2010, the US submitted to the United Nations Framework Convention on Climate Change (UNFCCC) a national-goal plan to reduce greenhouse gas by 17 percent by 2020, which includes enactment of relevant domestic law.

The Climate Action Plan, announced by President Obama in June 2013, emphasises promotion of the spread of renewable energy technology, and shows a policy that puts the introduction of advanced CCS technology as a precondition for financial support for overseas coal-fired power generation.

In December 2013, the Export-Import Bank of the United States (US Eximbank) introduced major regulations on financing CPPs and technology export. With future consequences of such financing regulations in mind, however, it is necessary to study and analyse in a multifaceted and comprehensive manner the following: 1) environmental regulations on domestic coal-fired power generation, 2) price competitiveness of coal-fired power generation, 3) global framework for climate-change countermeasures, 4) trends of coal-fired power plants and technology export in other countries, and 5) domestic political dynamics.

D. Chapters 4 and 5

This analysis assumes the following two scenarios.

Table 6.2: Description of Scenarios

Efficiency Downgrade Scenario	Despite discontinued financing by MDBs and ECAs, construction of coal-fired power plants is continued by using alternative funds. Because there will be no more efficiency standards and environmental protection regulations imposed by MDBs and ECAs, improvement of coal-fired power generation efficiency is delayed.
Gas Conversion Scenario	A project, assuming financing from MDBs and ECAs, is partly deadlocked. Needs for new electric power development are satisfied by a gas-fired power generation project entitled to financing.

ECA = export credit agency, MDB = multilateral development bank.
Source: Author.

(1) Influence on the User Country of Coal-fired Power Generation

This study analyses how India and Indonesia are influenced when financing for construction of CPPs in them is discontinued. The following are the results.

- When scenario becomes a reality, the macroeconomies of both countries are influenced negatively depending on a combination of events.
- Delayed improvement of coal-fired power generation efficiency badly affects the GDP, current account balance, and electricity charge of the country as a result of increased coal import volume or decreased coal export volume.
- A shift to gas-fired power generation badly affects the GDP, current account balance, and electricity charge as a result of increased natural gas import volume.

- A shift to gas-fired power generation contributes to reduced CO_2 emissions. Because of failure to offset increased CO_2 emissions due to delay of concurrent improvement of coal-fired power generation efficiency, however, CO_2 emissions may become higher than in a business-as-usual scenario.

It should be noted that this analysis does not include evaluation for a change of initial investment cost. When comparing coal-fired and gas-fired power generation, the latter is smaller in initial investment cost. Therefore, to some extent, the negative effects of increased fuel cost will be absorbed by smaller amount of initial investment when using gas-fired instead of coal-fired power generation (see Appendix B).

(2) Influence on the Coal-exporting Country

This study analyses how Australia, Indonesia, and South Africa are influenced when financing coal-fired power generation in India, a coal-importing country, is discontinued. Following are the results.

- In actualised scenario of coal-fired power generation in India, the macroeconomy of the coal-exporting country is influenced both positively and negatively.
- Delayed improvement of coal-fired power generation efficiency in India has a positive effect on its GDP and current account balance through an increased coal import volume.
- Coal demand is decreased by a shift from coal-fired to gas-fired power generation, conceived to concurrently advance in the coal-importing country. The volume of Indian coal import may drop greatly depending on a balance between 'delayed efficiency improvement' and 'shift to gas-fired power generation.' In this case, the GDP and current account balance of the coal-exporting country are lowered.

6.2. Policy Implications

Economic efficiency is the biggest reason to favour coal-fired power generation. Such a trend is particularly noticeable in developing countries with weak financial base or where the people have low income/purchasing power. Every country makes efforts to develop its economy. A stable and inexpensive supply of electric power is essential for economic development. In this sense, coal-fired power generation plays an important part.

On the other hand, with global warming now an international issue and the developing countries being asked to respond to pollution problems, there is a demand to utilise energy as cleanly as possible. Given such a situation, the most suitable energy is nuclear power and renewable energy, followed by gas-fired power. The extremely big investment and special skills required for nuclear power generation, however, serve as obstacles to its utilisation in the developing countries. Renewable energy is not only expensive but also has system stabilisation problems at the time of large-scale introduction of wind- and solar-power generation. Gas-fired power generation is more advantageous than nuclear power and renewable energy in terms of cost and investment barriers, but less advantageous than coal-fired power generation in terms of economic efficiency. Given such conditions, utilisation of high-efficiency coal-fired power generation is very meaningful if it can use its economic superiority and stable availability of supply while controlling its weakness This is a strong option capable of simultaneously achieving the three pillars in electric power supply: 'supply stability,' 'economic efficiency', and 'environmental friendliness,' at a high dimension.

The question now is how the ongoing restrictions on financing construction of new coal-fired power plants would figure in all this. As analysed in Chapter 4, the most possible scenario is that construction of coal-fired power plants is continued by using alternative funds. The problem, however, is that alternative fund sources may not be as stringent with environmental standards as MDBs and ECAs. The developing country would obtain satisfactory results in the stable supply and economic efficiency of electric power through coal-fired power generation. However, this will damage the country's 'environmental friendliness,' increase air pollution and CO_2 emissions, and drive it away from the world movement towards a low-carbon society.

The restrictions imposed by MDBs and ECAs on financing coal-fired power generation are intended to inhibit construction of CPPs with high environmental load. The results of this study, however, indicate that the restrictions on financing may run counter to the intended purpose.

Why then do the restrictions on financing by MDBs and ECAs not function as intended? It is because the restrictions are only imposed by MDBs and ECAs of advanced countries. ECAs in non-OECD countries, on the other hand, would continue to finance coal-fired power generation. Of those financial institutions, how many would impose stringent environmental regulations on a debtor? To achieve maximum effects of restrictions on financing, all MDBs and ECAs in the world have to agree to the restrictions. But it is not realistic or it is evident that it would take a considerably long time to realise that. If that is the case, one may think that leaving the existing financing framework and allowing financing CPPs under a stringent environment control would be a shortcut to a low-carbon society.

APPENDIX A

Analysis for South Africa

Other than the member countries of the East Asia Summit (EAS), there are countries with a high ratio of coal-fired power generation in their electric power supply. The following uses South Africa for analysis using the same method discussed in Chapter 4.

Table A.1: Assumption of Average Efficiency of Coal-fired Power Plants

BAU scenario	39.3%*
Efficiency down scenario	34.3% (BAU -5%)

BAU = business as usual, CPP = coal-fired power plant.

* The Institute of Energy Economics, Japan, *Asia/World Energy Outlook 2013,* Reference scenario.

Source: Authors.

Table A-2. Assumption of Fuel Share in Power Generation

BAU scenario	Coal	87.3%*
	Gas	0%*
15% Gas conversion scenario	Coal	-13.1% (-15% of 87.3%)
	Gas	+13.1%
30% Gas conversion scenario	Coal	-26.2% (-30% of 87.3%)
	Gas	+26.2%

BAU = business as usual.

* The Institute of Energy Economics, Japan, *Asia/World Energy Outlook 2013,* Reference scenario.

Source: Authors.

Table A.3: Assumption of Fuel Cost for Power Generation

Coal price	Domestic	$25/tonne*
	Export	$110/tonne**
Gas price	Import	$12.7/MMBtu**

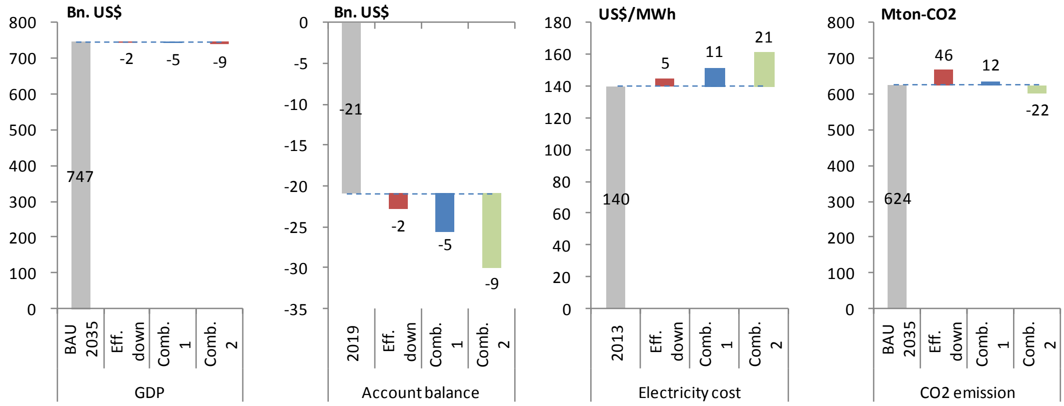
MMBtu = million British thermal unit.
*South African Coal Report.
**International Energy Agency, *World Energy Outlook 2013,* New Policy Scenario.
Source: Authors.

The calculation result indicates that delayed improvement of coal-fired power generation efficiency and a shift to gas-fired power generation will influence South Africa's macroeconomy.

The degree of influence increases in the order of efficiency downgrade, combination 1, and combination 2 scenarios, corresponding to a 1.2 percent increase of GDP (2035), 44 percent increase of current account balance (2019), and 15 percent increase of electric charge (2013) at maximum.

On the other hand, CO_2 emissions are reduced more as a shift volume to gas-fired power generation becomes larger. In the combination 2 scenario, CO_2 emissions are expected to be four percent lower than in the BAU scenario. However, in the combination 1 scenario, for instance, CO_2 emissions become higher than in BAU because increased CO_2 emissions due to lower efficiency cannot be offset by a reduction effect brought about by a shift to gas-fired power generation.

Figure A.1: Calculated Result (South Africa)



bn = billion, CO_2 = carbon dioxide, Comb. = Combination, Eff. = Efficiency, Mton = megaton, MWh = megawatt-hour.

Electricity price in 2013: Simple average of sector-wise tariff effective during FY2013.

Sources: The Institute of Energy Economics, Japan, *Asia/World Energy Outlook 2013,* Oct 2013; Reference scenario: International Monetary Fund, *World Economic Outlook* April 2014; ESKOM.

APPENDIX B

Effects of Reduction in Capital Cost

Chapter 4 analyses the economic impact of change of fuel cost of power generation. Generally, ratio of fuel cost in total cost is very high in thermal power generation.

Initial investment affects power-generation cost. In the efficiency downgrade scenario, the initial investment is reduced by switching from initially planned high-efficiency power-generation facilities to low-efficiency power-generation facilities. Switching to low-generation efficiency increases fuel cost, but the lower initial investment offsets part of the increased cost. In the gas-conversion scenario, switching from high-efficiency coal-fired power generation to natural-gas CCGT decreases the initial investment. Also, the decreased initial investment can offset part of increased fuel cost associated with a shift to gas-fired power generation. Accordingly, an analysis was made on the degree of influence of the decreased initial investment.

The construction cost assumption of coal-fired power plants (CPPs) and natural-gas CCGT employed the values in the 'Updated Capital Cost Estimates for Utility Scale Electricity Generating Plants' issued by the US Energy Information Administration (EIA) in April 2013 because the report evaluates various electric power costs under constant conditions and was more recently employed in several analyses of power-generation costs.

It has to be noted that construction costs of power plants naturally differ depending on each power plant and each country. The EIA's cost data in this study are also estimated values of construction costs in the US under certain supposition. Accordingly, the construction cost in the target country of this study is not shown. Furthermore, although it is considered apt to analyse based on the construction costs of subcritical pressure CPPs, ultra supercritical (USC) pressure CPPs, and natural gas CCGT, this study utilised the construction costs of supercritical pressure CPPs, IGCC, and natural gas CCGT for convenience because no distinctions are found in the EIA report.

These analytical results show the direction of influence by different construction costs, but do not allow measurement of the volume of influence.

Table B.1: Assumption of Initial Investment Cost

	Plant Description			Levelised Capital Cost [2012 US$/MWh]
	Plant type	Thermal efficiency (HHV)	Capacity factor	
Conventional coal	650MW SC	38.8%	85%	60.0
IGCC	600MW F class	39.2%	85%	76.1
Advanced combined cycle	400MW H class	53.1%	87%	15.7

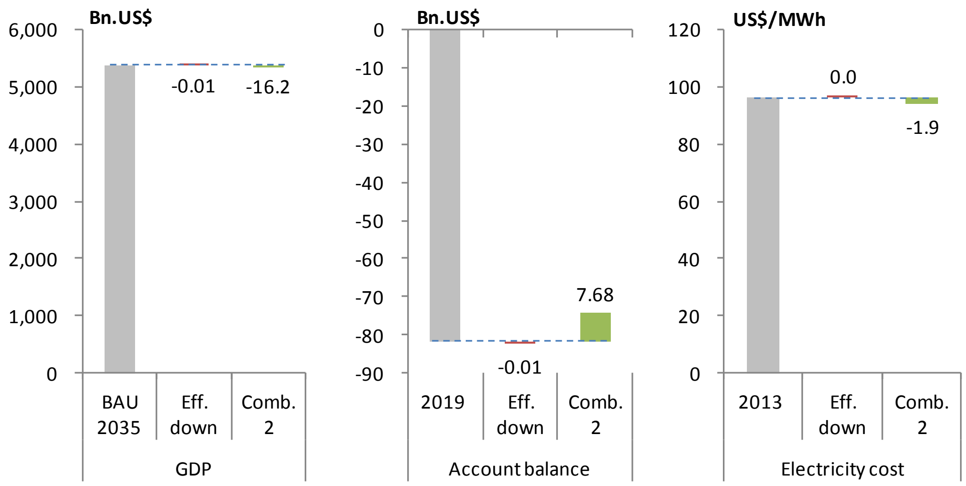
IGCC = integrated coal gasification combined cycle, HHV = higher heat value, MW = megawatt, MWh = megawatt-hour.
Source: US Energy Information Administration, *Updated Capital Cost Estimates for Utility Scale Electricity Generating Plants,* April 2013.

The following shows the calculation results of influence based on these assumptions. To check the direction of influence, calculation was made only on the efficiency downgrade and combination 2 (Efficiency downgrade + Gas conversion 30 percent).

Based on the calculation results, a decreased initial investment softens the influence on the macroeconomy of each country and case. The degrees of softening differ depending on the country and case, an increment of fuel cost may be considerably offset depending on the combined conditions.

As mentioned, sufficient information on the assumed initial investment has not been obtained. These analytical results show the direction of influence on the macroeconomy of the reduced initial investment, but do not allow measurement of the degree of influence. It was confirmed that reduced initial investment was effective in softening the influence on the macroeconomy, but whether it can fully offset the negative effect in comparison with the benchmark remains uncertain.

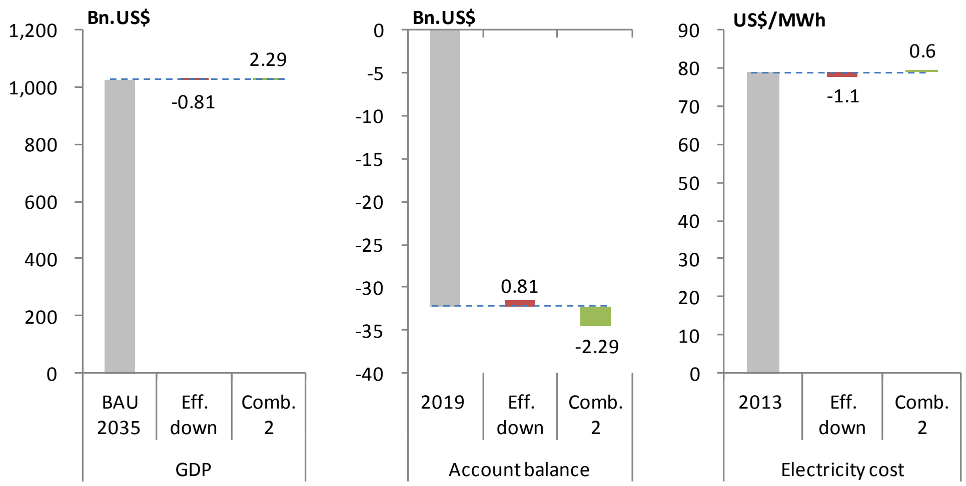
Figure B.1: Combined Effect of Fuel Cost and Capital Cost of Coal-fired Power Plants (India)



BAU = business as usual, bn = billion, Comb. = Combination, CPP = coal-fired power plant, Eff. = Efficiency, GDP = gross domestic product, MWh = megawatt-hour.

Source: Economic Research Institute for ASEAN and East Asia, *Analysis on Energy Saving Potential in East Asia,* June 2013; BAU scenario: International Monetary Fund, *World Economic Outlook April 2014:* CEA.

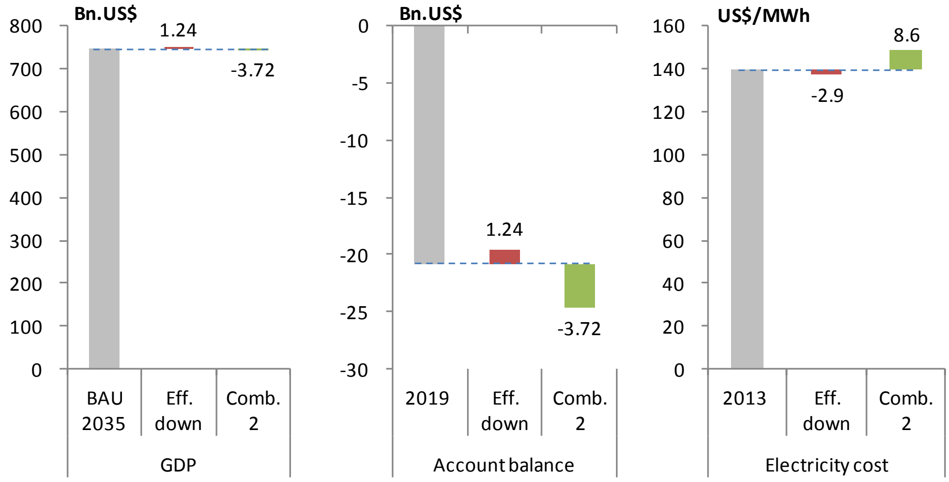
Figure B.2: Combined Effect of Fuel Cost and Capital Cost of Coal-fired Power Plants (Indonesia)



BAU = business as usual, bn = billion, Comb. = Combination, CPP = coal-fired power plant, Eff. = Efficiency, GDP = gross domestic product, MWh = megawatt-hour.

Source: Economic Research Institute for ASEAN and East Asia, *Analysis on Energy Saving Potential in East Asia,* June 2013; BAU scenario: International Monetary Fund, *World Economic Outlook,* April 2014; PLN.

Figure B.3: Combined Effect of Fuel Cost and Capital Cost of Coal-fired Power Plants (South Africa)



BAU = business as usual, bn = billion, Comb. = Combination, CPP = coal-fired power plant, Eff. = Efficiency, GDP = gross domestic product, MWh = megawatt-hour.

Source: The Institute of Energy Economics, Japan, *Asia/World Energy Outlook 2013*, Oct 2013; Reference scenario: International Monetary Fund, *World Economic Outlook*, April 2014; ESKOM.

APPENDIX C

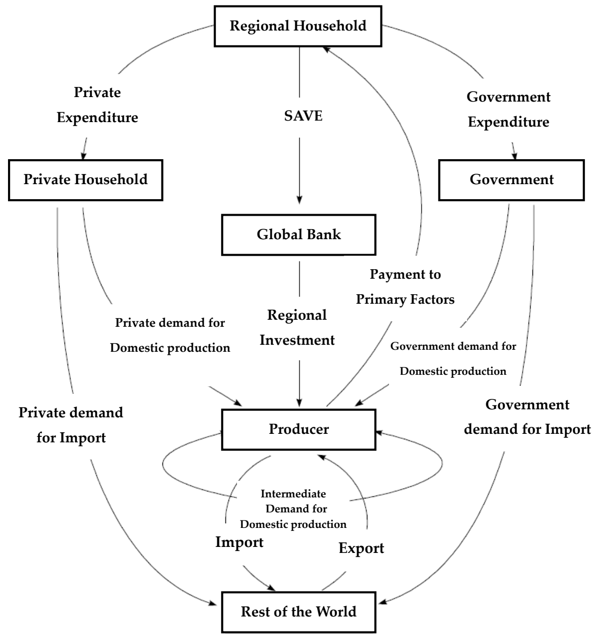
Effects of Electricity Price Increase

C.1. Methodology of Analysis

This chapter quantitatively analyses how the macroeconomy is influenced by lower coal-fired power-generation efficiency and a shift from coal-fired to natural-gas-power generation. Such changes in power generation influence producers and consumers not only through higher electricity charge but through increased import of fossil fuels as well. In evaluating these effects on the macroeconomy, a global trade analysis project (GTAP) model is utilised, one of the typical multi-area, multisectoral computable general equilibrium models.

In the GTAP model, there is a producer, a private household, and a government as economic agents in a country/region. The private household and the government are treated as a regional household since they spend the same way in response to price and income changes. The private household receives factor income by providing labour, capital, and land to the producer. The difference between factor income and expenditure becomes saving, which flows to the investment of the producer. The model identifies changes of economic indicators resulting from the behaviour of these economic agents in response to changes in prices of goods and services.

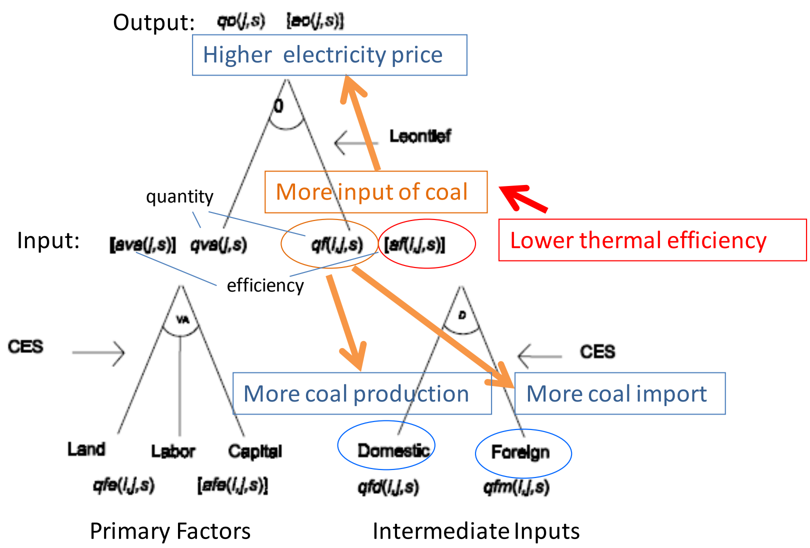
Figure C.1: Model Framework of GTAP



Source: Global Trade Analysis Project.

An increase in electricity charge by lower coal-fired power-generation efficiency and a shift from coal-fired to natural-gas-fired power generation is expressed by changing the input efficiency of coal and natural gas in the production function of the electric power sector.

Figure C.2: Impact of Lower Thermal Efficiency of Coal-fired Power Generation Production Function



Source: Global Trade Analysis Project.

C-2. Precondition of Analysis

With India and Indonesia as study target countries, this chapter sets the following cases.

Table C.1: Case Setting

	Eff. downgrade	Gas conversion
Efficiency downgrade case	-5% than BAU	-
Gas conversion case; Combination scenario 1	-5% than BAU	15% of CPPs will be converted
Gas conversion case; Combination scenario 2	-5% than BAU	30% of CPPs will be converted

BAU = business as usual, CPP = coal-fired power plant, Eff. = Efficiency.
Source: Authors.

The efficiency downgrade case assumes a five-percent drop of coal-fired power generation efficiency. It drops from 37.6 percent to 32.6 percent in India and from 38.7 percent to 33.7 percent in Indonesia. Increased coal input boosts the electricity charge by 6.0 percent and 3.2 percent in both countries, respectively.

The combination 1 case assumes partial replacement of a coal-fired power plant construction project by a natural-gas-fired power plant in addition to a five-percent drop of coal-fired power generation efficiency. In India, 15 percent of coal-fired power generation is replaced by natural- gas-fired power generation, decreasing the share of coal-fired power generation in electric power generation from 67.7 percent to 57.5 percent. In Indonesia, 15 percent of coal-fired power generation is replaced by natural-gas-fired power generation, decreasing the share of coal-fired power generation in electric power generation from 42.0 percent to 35.7 percent. The share of natural-gas-fired power generation increases by 10.2 percent and 6.3 percent points in both countries, respectively, and the electricity charge in India and Indonesia increases by 9.7 percent and 9.1 percent, respectively, due to lower coal-fired power-generation efficiency and increased natural-gas-fired power generation whose fuel cost is relatively high.

The combination 2 case assumes a further shift from coal-fired power generation to natural-gas-fired power generation. In India and Indonesia, 30 percent or coal-fired power generation is replaced by natural-gas-fired power generation, replacing the shares of coal-fired and natural-gas-fired power generation in electric power generation by 20.3 percent and 12.6 percent points, respectively. The electricity charge in India and Indonesia rises by 13.4 percent and 15.6 percent, respectively.

Table C.2: Electricity Price Change, by Case

	India	**Indonesia**
Average retail power price	US$96/MWh	US$79/MWh
Efficiency downgrade	+US$5.8/MWh（+6.0%）	+US$2.5/MWh（+3.2%）
Combination 1	+US$9.4/MWh（+9.7%）	+US$7.2/MWh（+9.1%）
Combination 2	+US$12.9/MWh（+13.4%）	+US$12.3/MWh（+15.6%）

MWh = megawatt-hour.
Source: Authors.

Since India’s domestic natural gas resources are limited and spare production capacity is low, it is assumed that the country’s natural gas production volume remains unchanged in each case.

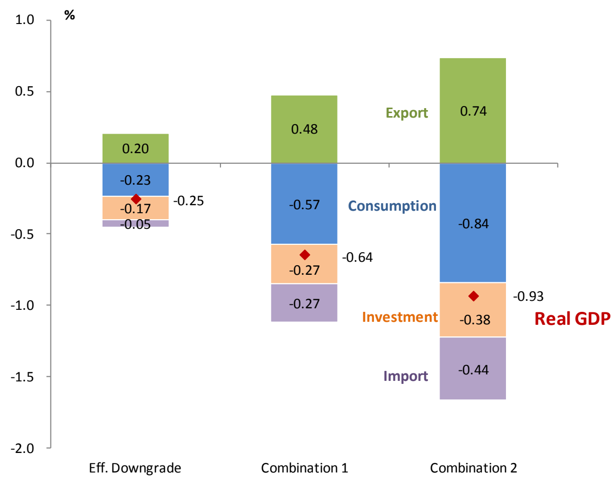
C-3. Result of Analysis

C-3-1 Influence on the Macroeconomy of India

(1) Influence on the Real GDP

For India, a net importer of coal and natural gas, lower coal-fired power-generation efficiency and electric power shift from coal to natural gas help increase fossil fuel import and expand an energy trade deficit. In addition, the higher electricity price due to increased fuel cost lowers real consumption and leads to higher production costs and prices in many manufacturing businesses, thereby deteriorating economic activities. On the other hand, in some industries, relaxation of domestic supply and demand, etc. decreases the cost of primary factors such as capital, and lowers the prices, resulting in enhanced international competitiveness and increased export. Consequently, however, the negative effects of increased fuel import and higher electricity price are bigger and the real GDP drops by 0.25 percent in the efficiency downgrade case, 0.64 percent in the combination 1 case, and 0.93 percent in the combination 2 case.

Figure C.3: Real GDP Change in India



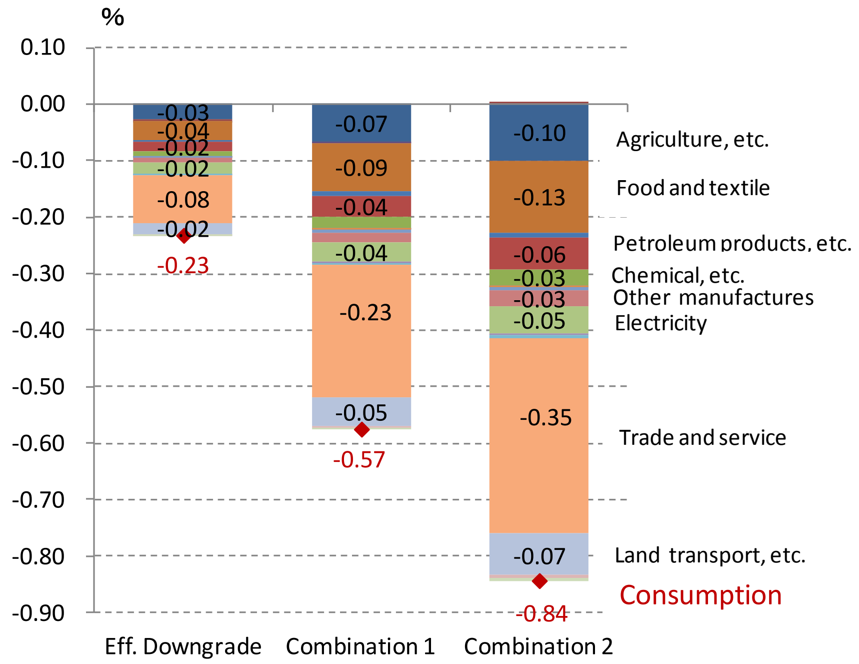
Eff. = Efficiency, GDP = gross domestic product.
Source: Authors.

The following describes how higher electricity charge, change of fossil fuel import, etc. influence final consumption, production in each industry, export/import, and prices in India.

(2) Influence on Consumption

Higher electricity price increases expenditure for electricity purchase in final consumption and decreases real consumption. Lower final consumption results in lower production, leading to lower income. In the efficiency downgrade case, combination 1 case, and combination 2 case, real final consumption drops 0.33 percent, 0.82 percent, and 1.2 percent, respectively. This contributes to a 0.23 percent, 0.57 percent, and 0.84 percent reduction of the real GDP, respectively. Above all, the demand decrease is relatively high in trade and services, agriculture, and food and textile sectors. Household power consumption also drops by 1.8 percent to 4.5 percent.

Figure C.4: Real Consumption Change in India (Contribution to Real GDP)



Eff. = Efficiency.
Source: Authors.

(3) Influence on Production, Export/Import, and Prices

1) Influence on Energy Production and Price

In the efficiency downgrade case, lower coal-fired power generation efficiency increases coal demand for power generation, boosting domestic coal production by 6.7

percent. Also, due to tight demand and supply, etc., the domestic coal price goes up by 17.1 percent, coal import price goes up by 2.9 percent, causing the average coal price for business use to increase by 10.6 percent.

In the combination 1 case, the demand increase effect due to lower power-generation efficiency is almost offset by the demand decrease effect due to a shift from coal to natural gas; coal demand for power generation declines only slightly; and coal production and price change very little. On the other hand, due to a higher demand for natural gas for power generation, both the domestic production price and import price of natural gas go up, causing the average price for business use to increase by 6.4 percent.

In the combination 2 case, a shift to natural gas is further accelerated, coal demand for power generation drops, decreasing coal production by 5.4 percent. Due to relaxed supply and demand, etc., the domestic coal production price drops by 10.5 percent, causing the average price for business use to drop by 7.6 percent. On the other hand, the average natural gas price for business use goes up by 7.3 percent.

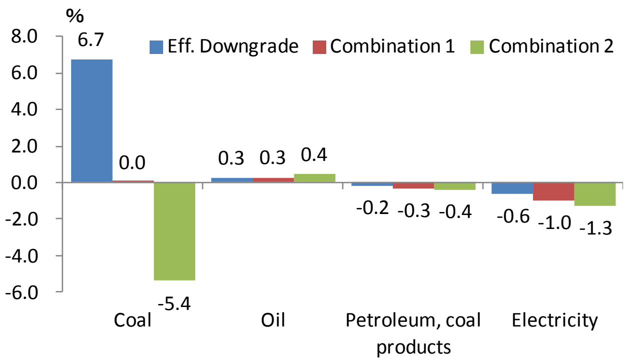
Electric power demand drops due to a price hike, resulting in 0.6 percent, 1.0 percent, and 1.3 percent lower electric power production in the efficiency downgrade, combination 1, and combination 2 cases, respectively.

Table C.3: Energy Price Change in India

		Coal	Oil	Gas	Petroleum products, etc.	Electricity
Eff. Downgrade	Production price	+17.1%	−0.1%	−0.1%	−0.0%	+6.0%
	Import price	+2.9%	−0.0%	+0.0%	+0.0%	+0.1%
	Price to firms	+10.6%	−0.0%	−0.1%	−0.0%	+6.0%
Combination 1	Production price	−1.2%	−0.1%	+13.8%	−0.0%	+9.7%
	Import price	−0.1%	+0.0%	+1.0%	+0.1%	+0.1%
	Price to firms	−0.8%	−0.0%	+6.4%	−0.0%	+9.7%
Combination 2	Production price	−10.5%	−0.2%	+18.7%	−0.1%	+13.4%
	Import price	−1.4%	+0.0%	+1.6%	+0.1%	+0.1%
	Price to firms	−7.6%	−0.0%	+7.3%	−0.1%	+13.4%

Eff. = Efficiency.
Source: Authors.

Figure C.5: Energy Production Change in India



Eff. = Efficiency.
Source: Authors.

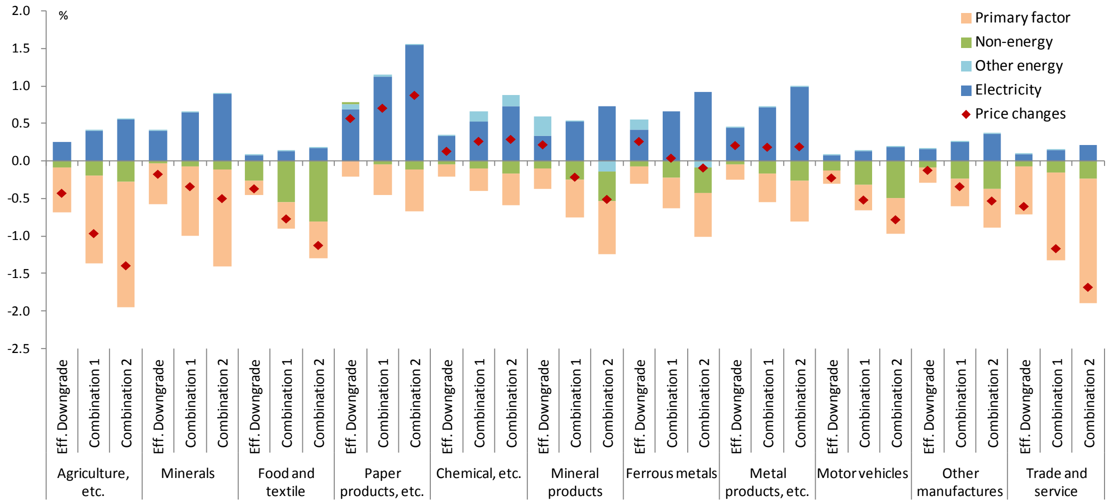
(2) Influence on Production and Prices in Non-energy Industries

Higher electricity price adds to electric power cost in each industry, resulting in higher product prices. On the other hand, lower domestic final demand relaxes supply and demand for many goods and services, resulting in lower product prices. Then, lower production in some industries applies pressure of decreased demand to primary factors such as capital and labour to contract demand. Furthermore, in structural adjustment to make up for increased electric power cost, distribution to primary factors (i.e. a ratio of value added) decreases, which in turn lowers price, contributing to lower production cost. Production cost is also influenced by increased/decreased coal price, increased natural gas price, and so on.

In energy-intensive industries such as chemical, paper, and metal products, effects of higher cost by higher electric power price become more outstanding and production prices rise in all cases due to comprehensive action of these factors. On the other hand, in industries such as agriculture, food and textile, other manufactures, and trade and services, effects of lower primary factor price, etc. are bigger and production prices in these industries drop in all cases.

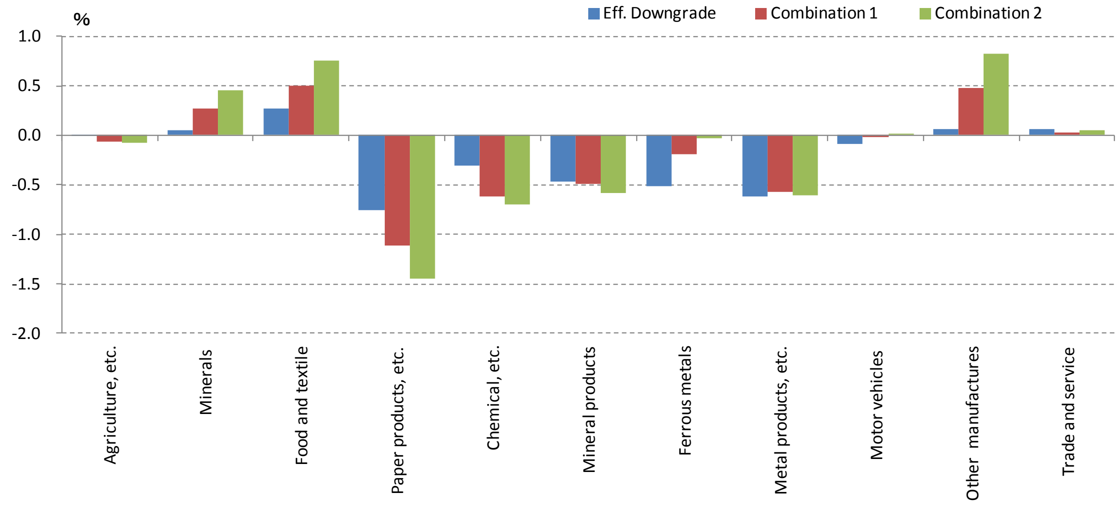
Because of smaller domestic demand attributable to higher prices and decreased real consumption, production drops in many manufacturing businesses such as chemical, paper, and metal products. On the other hand, in some industries such as food and textile, and other manufactures, global competitiveness is enhanced by lower product prices, increase of external demand led by increased export and advanced import substitution exceeds the decrease in domestic final consumption, thus expanding production.

Figure C.6: Domestic Production Cost Change of Non-energy Industry in India



Eff. = Efficiency.
Source: Authors.

Figure C.7: Production Amount Change of Major Non-energy Industry in India



Eff. = Efficiency.
Source: Authors.

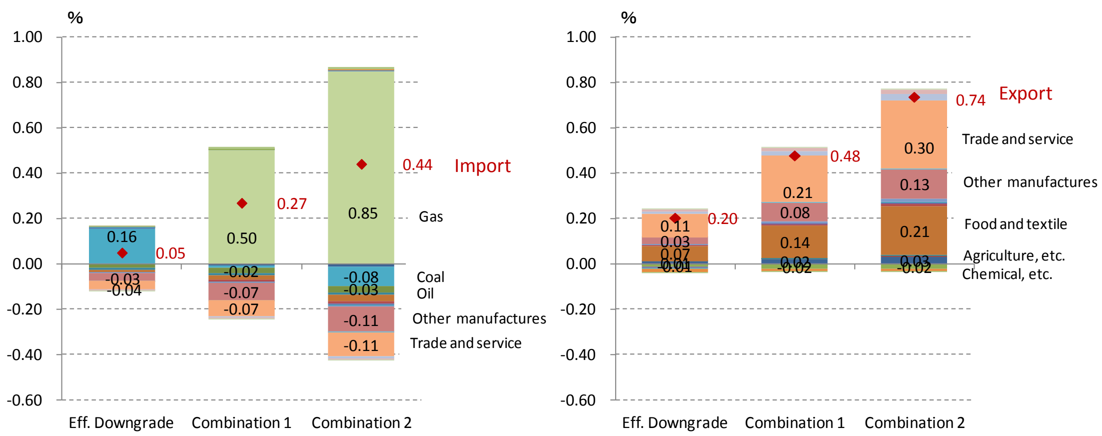
(3) Influence on Export/Import

India is a net importer of coal and natural gas. In the efficiency downgrade case, coal import increases due to expanded coal demand for electric power, contributing to approximately 0.16 percent decline of India's GDP. In the combination 1 case, natural gas demand for electric power increases and increased import of natural gas contributes to 0.5 percent decline of GDP. In the combination 2 case, contribution of increased import of natural gas to lower GDP further expands to 0.85 percent. Coal import decreases, but its contribution to higher GDP is only approximately 0.08 percent. In all cases, trade and services, and oil import drop due to decreased domestic demand, and so on. Also, development of import substitution decreases import of other manufactures.

Concerning export, higher product prices decrease export by the chemical industry, and so on. On the other hand, global competitiveness is enhanced in the food and textile industry, other manufactures, and trade and services industry where product prices drop, expanding export.

In total, Indian import decreases GDP by 0.05 percent, 0.27 percent, and 0.44 percent in the efficiency downgrade, combination 1, and combination 2 cases, respectively, whereas Indian export contributes to 0.20 percent, 0.48 percent, and 0.74 percent increase of GDP for these cases, respectively.

Figure C.8: Real Export/Import Change in India (Contribution to Real GDP)



Import

Export

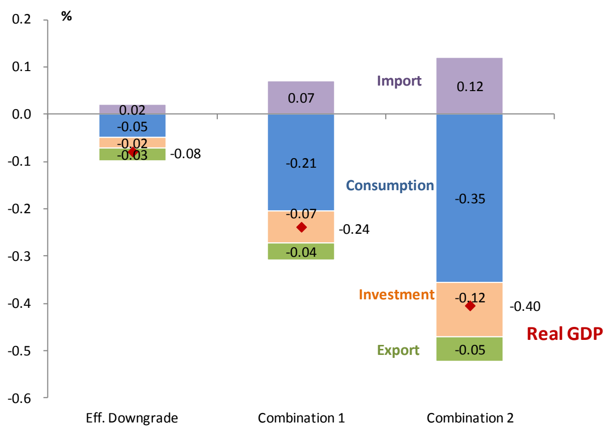
Eff. = Efficiency.
Source: Authors.

C-3-2 Influence on the Macroeconomy of Indonesia

(1) Influence on Real GDP

For Indonesia, a net exporter of coal and natural gas, lower coal-fired power generation efficiency and an electric power shift from coal to natural gas help increase domestic supply of fossil fuels and decrease export. In addition, higher electricity price due to increased fuel cost lowers real consumption, leads to higher production costs and prices in energy-intensive industries such as ferrous metal, thereby decreasing a ratio of value added and deteriorating economic activities. On the other hand, in some industries such as food and textile, relaxation of domestic supply and demand, structural adjustment, etc. decrease the cost of primary factors such as capital, lowers product prices, resulting in enhanced international competitiveness and increased export. Consequently, however, the negative effects of higher electricity price and decreased fuel export are bigger and real GDP drops by 0.08 percent in the efficiency downgrade case, 0.24 percent in the combination 1 case, and 0.40 percent in the combination 2 case, respectively.

Figure C.9: Real GDP Change in Indonesia



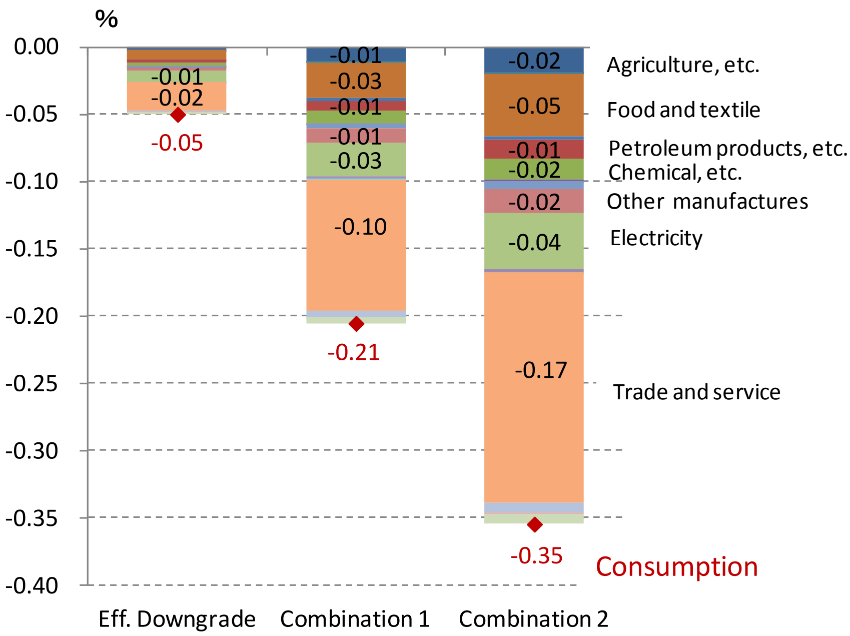
Eff. = Efficiency, GDP = gross domestic product.
Source: Authors.

The following specifically describes how higher electricity charge, change of fossil fuel export, etc. influence final consumption, production in each industry, and export/import and prices in Indonesia.

(2) Influence on Consumption

Higher electricity price increases expenditure for electricity purchase in final consumption and decreases real consumption. Lower final consumption and higher electric power cost result in lower production and decreased ratio of value added, leading to lower income. In the efficiency downgrade case, combination 1 case, and combination 2 case, real final consumption drops by 0.07 percent, 0.29 percent, and 0.50 percent, respectively. This contributes to 0.05 percent, 0.21 percent, and 0.35 percent reduction of real GDP, respectively Above all, demand decrease is relatively high in trade and services, and food and textile sectors. Household power consumption also drops by 1.0 percent to 4.6 percent.

Figure C.10: Real Consumption Change in Indonesia (Contribution to Real GDP)



Eff. = Efficiency.
Source: Authors.

(3) Influence on Production, Export/Import, and Prices

1) Influence on Energy Production, Export/Import, and Prices

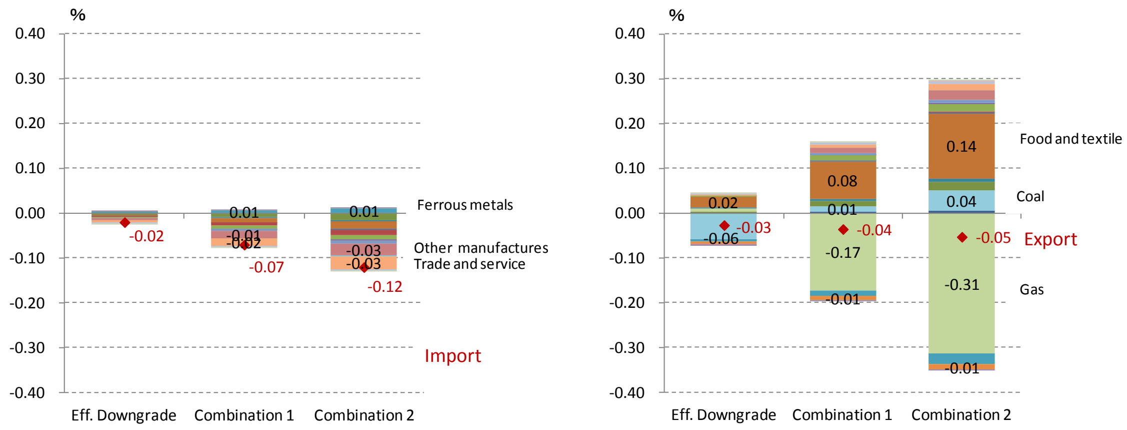
Indonesia is a net exporter of coal and natural gas. Since the demand change of coal and natural gas for power generation assumed in each case is mainly absorbed by adjusting their export, its influence on domestic production and prices is limited.

In the efficiency downgrade case, lower coal-fired power-generation efficiency increases coal demand for power generation. In response to that, domestic coal production increases by 0.6 percent and coal export drops. Decreased export lowers GDP by 0.06 percent. The influence on coal price is limited, increasing domestic production price only by 1.0 percent.

In the combination 1 case, the increased demand effect due to lower power generation efficiency is almost offset by the decreased demand effect due to a shift from coal to natural gas, coal demand for power generation declines only slightly, having very little influence on coal price, production, and trade. On the other hand, due to a higher demand for natural gas for power generation, natural gas production increases by 1.7 percent, but its export drops. Contribution of decreased export to GDP is -0.17 percent. Domestic production price of natural gas increases only by 0.5 percent.

In the combination 2 case, a shift to natural gas is further accelerated, coal demand for power generation drops. In response to that, domestic coal price drops slightly by 0.8 percent, increasing coal export under almost the same coal production volume. This increment of coal export boosts GDP by 0.04 percent. On the other hand, natural gas production increases by 3.1 percent in response to increased natural gas demand, but its export drops. Contribution of decreased export to GDP is -0.31 percent. Domestic production price of natural gas increases by 1.0 percent.

Figure C.11: Real Export/Import Change in Indonesia (Contribution to Real GDP)



Import

Export

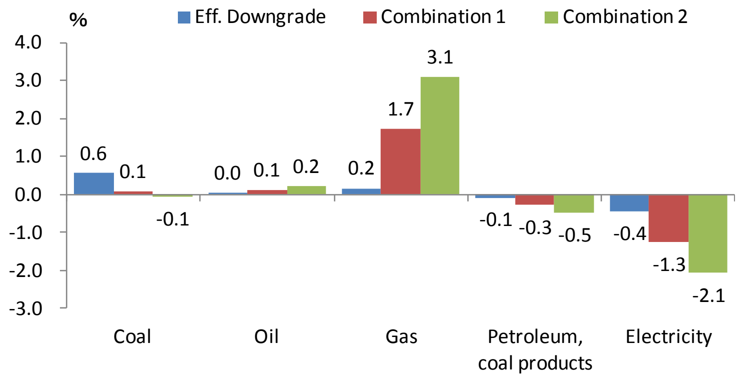
Eff. = Efficiency.
Source: Authors.

Table C.4: Energy Price Change in Indonesia

		Coal	Oil	Gas	Petroleum products, etc.	Electricity
Eff. Downgrade	Production price	+1.0%	−0.0%	−0.0%	−0.0%	+3.2%
	Import price	+0.3%	−0.0%	−0.0%	+0.0%	+0.0%
	Price to firms	+1.0%	−0.0%	−0.0%	−0.0%	+3.2%
Combination 1	Production price	−0.2%	−0.1%	+0.5%	−0.1%	+9.1%
	Import price	−0.1%	−0.0%	+0.1%	−0.0%	+0.0%
	Price to firms	−0.2%	−0.1%	+0.5%	−0.0%	+9.1%
Combination 2	Production price	−0.8%	−0.2%	+1.0%	−0.1%	+15.6%
	Import price	−0.2%	−0.0%	+0.2%	−0.0%	+0.0%
	Price to firms	−0.7%	−0.1%	+1.0%	−0.1%	+15.6%

Eff. = Efficiency.
Source: Authors.

Figure C.12: Energy Production Change in Indonesia



Eff. = Efficiency
Source: Authors.

(2) Influence on Production, Export/Import, and Prices in the Non-energy Industries

An increase in electricity price adds to electric power cost in each industry, pushing up prices. On the other hand, decreased domestic final demand relaxes supply and demand of many goods and services, lowering prices. Lower production in some industries applies pressure of decreased demand to primary factors such as capital and labour. Furthermore, in structural adjustment to make up for increased electric power cost, a distribution to primary factors (i.e. a ratio of value added) decreases, which in turn lowers price, contributing to lower production cost.

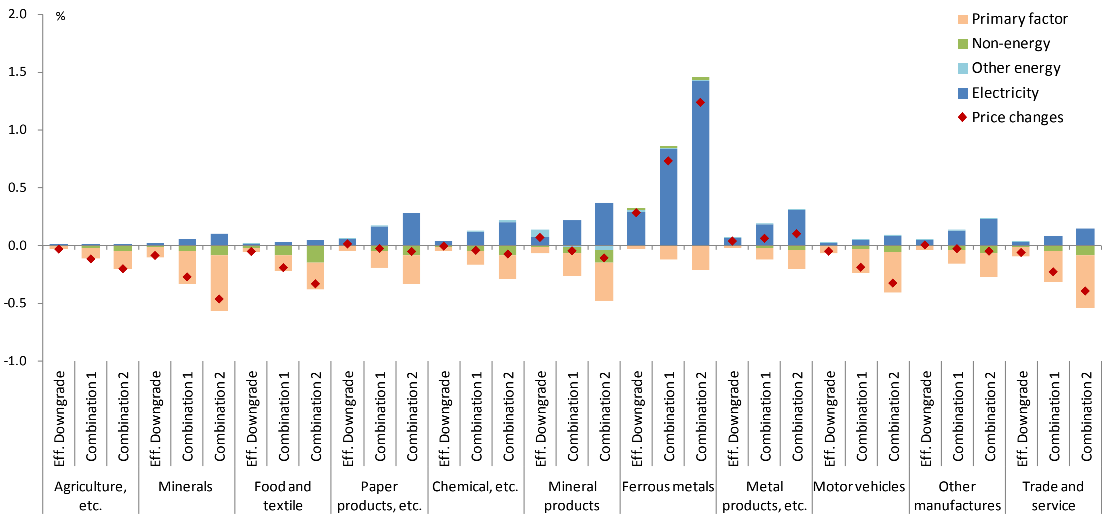
By comprehensive action of these factors, the effect of increased cost due to higher electricity price is more remarkable in energy-intensive industries such as ferrous metal, increasing production prices in all cases. In the combination 2 case, production price of ferrous metal goes up by 1.2 percent. On the other hand, the effect of lower primary factor prices, etc. is bigger in industries such as food and textile, and trade and services, lowering production prices in these industries. Except for ferrous metal, however, the effect on prices in major industries is limited, remaining at the variation width of 0.5 percent or less in all of them.

Concerning import, many products are imported less because of decreased domestic demand due to lower real consumption, boosting GDP by 0.02 percent, 0.07 percent, and 0.12 percent in the efficiency downgrade case, combination 1 case, and combination 2 case, respectively. For ferrous metal, however, higher domestic production price lowers competitiveness and increases import (Figure C.11).

Concerning export, coal and natural gas export decreases or increases according to an increase or decrease in domestic demand. In industries such as food and textile, lower domestic production price enhances global competitiveness, expanding export. Nonetheless, the effect of decreased export of fossil fuels is relatively big after all and Indonesian export decreases GDP by 0.03 percent, 0.04 percent, and 0.05 percent in the efficiency downgrade case, combination 1 case, and combination 2 case, respectively (Figure C.11).

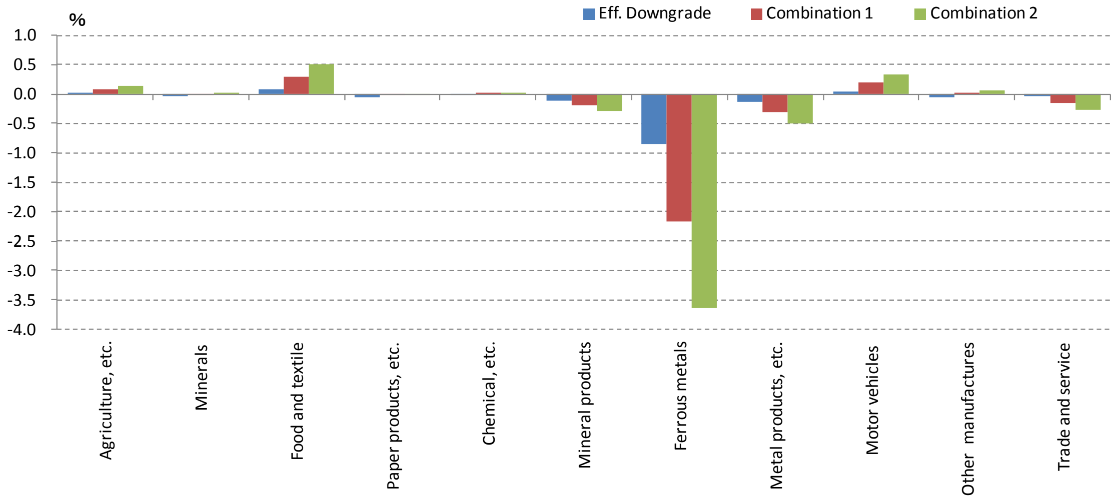
The change status of production differs depending on the industry. Decreased domestic demand reduces production of mineral products, trades and services, and so forth. Above all, domestic production of ferrous metal drops by 3.6 percent in the combination 2 case because of increased import due to deteriorated price competitiveness in addition to decreased domestic demand. In contrast, in industries such as food and textile, an increase in export exceeds the decrease in domestic demand, boosting production slightly.

Figure C.13: Domestic Production Cost Change of Non-energy Industry in Indonesia



Eff. = Efficiency.
Source: Authors.

Figure C.14: Production Amount Change of Major Non-energy Industry in Indonesia



Eff. = Efficiency.
Source: Authors.